

NORTH RIVER AND NORTHWEST RIVER MARSH GAME LANDS AQUATIC INVENTORY

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Introduction

The Pasquotank River Basin, which originates in Virginia, lies in the northeastern portion of North Carolina and drains into the Albemarle Sound. This watershed encompasses 3,697 square miles in area and drains portions of 10 North Carolina counties, making it the fifth largest river basin in the state. However, only 464 stream miles lie within the river basin, as most of the surface water is contained in estuaries and wetlands, along with 868,000 acres of saltwater. The waters of the Pasquotank are also "black" waters, stained by the naturally occurring acidic tannins that leach from the organic soils of the surrounding land. Two state-owned game lands, North River Game Land and Northwest River marsh Game Land, lie within the northern portion of the Pasquotank River Basin.

North River Game Land is located along the North River on the Camden and Currituck county line in the Great Swamp, approximately 20 km south of the Virginia border and 20 km east of Elizabeth City. The game land, which currently encompasses 16,246 acres, was purchased and donated as a series of parcels. The North Carolina Wildlife Resources Commission (NCWRC) purchased the initial 2 parcels in 1970 from Virginia Beach Aviation, which totaled slightly over 6,100 acres. Subsequently, additional adjacent parcels have been obtained from primarily the North Carolina Nature Conservancy, with 2 parcels attained from the Conservation Fund and a private landowner. As the game land's name indicates, the North River is the major waterway associated with the game land, along with Great Swamp, Maple Swamp, and a few creeks and canals that drain into the North or Pasquotank rivers. The major habitat type within the game land consists of forested wetlands with deep organic soils. Additionally, there are scattered stands of loblolly pine and Atlantic white cedar, with marsh areas covering the eastern portion of the game land in several locations. No active land management occurs on the game land, except for boundary posting. These tracts of land were acquired by the NCWRC for protection of sensitive habitat and water quality. In this regard, the area provides a secure resting and feeding area for resident and migratory waterfowl, and serves as a bear sanctuary. However, with the purchase of the Harrison Tract, the potential exists to create some waterfowl impoundments. Additionally, the game land serves as a low intensity hunting area for deer and other furbearers, and fishing opportunities also are available on the game land.

Northwest River Marsh Game Land is located along the Northwest River and Virginia border in northern Currituck County. The game land, which currently encompasses 3,298 acres, was purchased and donated as a series of parcels. The NCWRC purchased the initial 2 parcels in 1948 and 1950 from private landowners, which totaled slightly over 1,250 acres. Subsequently, an additional parcel was donated from Ducks Unlimited in 1988, and 6 parcels have been obtained from North Carolina Nature Conservancy since 1998. As the game land's name indicates, the Northwest River is the major waterway associated with the game land, along with the Northwest River Marsh, Tull Creek and Tull Bay, and the numerous canals the drain into Tull Creek. The major habitat type within the game land consists of marsh with some stands of pond and loblolly pine. Several acres of ponds are also on the game land. No active land management occurs on the game land, except for boundary posting. These tracts of land were

acquired by the NCWRC for protection of sensitive habitat and water quality. In this regard, the area provides a secure resting and feeding area for resident and migratory waterfowl, and serves as a bear sanctuary. Additionally, the game land serves as a low intensity hunting area for deer and other furbearers, and fishing opportunities also are available on the game land.

Land use in the areas surrounding both game lands primarily consists of agriculture, as portions of the area have been ditched and drained, particularly near Northwest River Marsh Game Land. A visual survey of the area reveals numerous cotton, peanut, tobacco, and corn fields. We did not notice any active pastures, but they are likely present at low levels. Timber activity appeared to be minimal given the landscape. Overall, the terrain in proximity to the game lands is relatively undeveloped with Elizabeth City serving as the largest city in the adjacent Pasquotank County.

The objective of this project was to survey the North River Game Land and Northwest River Marsh Game Land for aquatic species, including freshwater mussels, sphaeriid clams, aquatic snails, crayfishes, and fishes. Our goals were to determine species presence, distribution, relative abundance, and relative health. The inventory primarily focused on waterways associated with the game lands within Camden and Currituck counties, North Carolina. A number of sites were surveyed along the game lands, which were accessed from the North and Northwest rivers, but a few of the tracts went unsurveyed due to a lack of accessibility and the likelihood of not finding additional species in the area. Figure 1 and Tables 1a and 1b detail the localities of all sites surveyed. The following sections provide results of the aquatic inventory for each of the taxa mentioned above. For purposes of this report, *Corbicula fluminea* (Asian clam) was grouped with the sphaeriid clams even though the 2 taxa belong to different families. It also should be noted that any plus or minus symbols listed after road numbers in the following tables represent whether we surveyed downstream or upstream, respectively.

Acknowledgements

We would like to thank the following people, without whose assistance this project would not have been possible: John M. Alderman (NCWRC) for reviewing and editing the report; Dale J. Davis and David Denton (NCWRC, Edenton Depot) for providing background and access point information regarding the game lands, and use of a boat; Dr. John E. Cooper, Dr. Arthur E. Bogan, and Dr. Wayne C. Starnes, Gabriela M. Hogue, Dr. Morgan E. Raley, and Lynn Fullbright from the NC State Museum of Natural Sciences for providing assistance with identifications of crayfishes, mollusks, and fishes, respectively; Dr. Gerald L. Mackie from the University of Guelph, Ontario, Canada, for providing assistance with sphaeriid identifications. We also would like to thank the landowners and residents of Camden and Currituck counties, North Carolina, who allowed us to work on their property and showed an interest in their local natural history.

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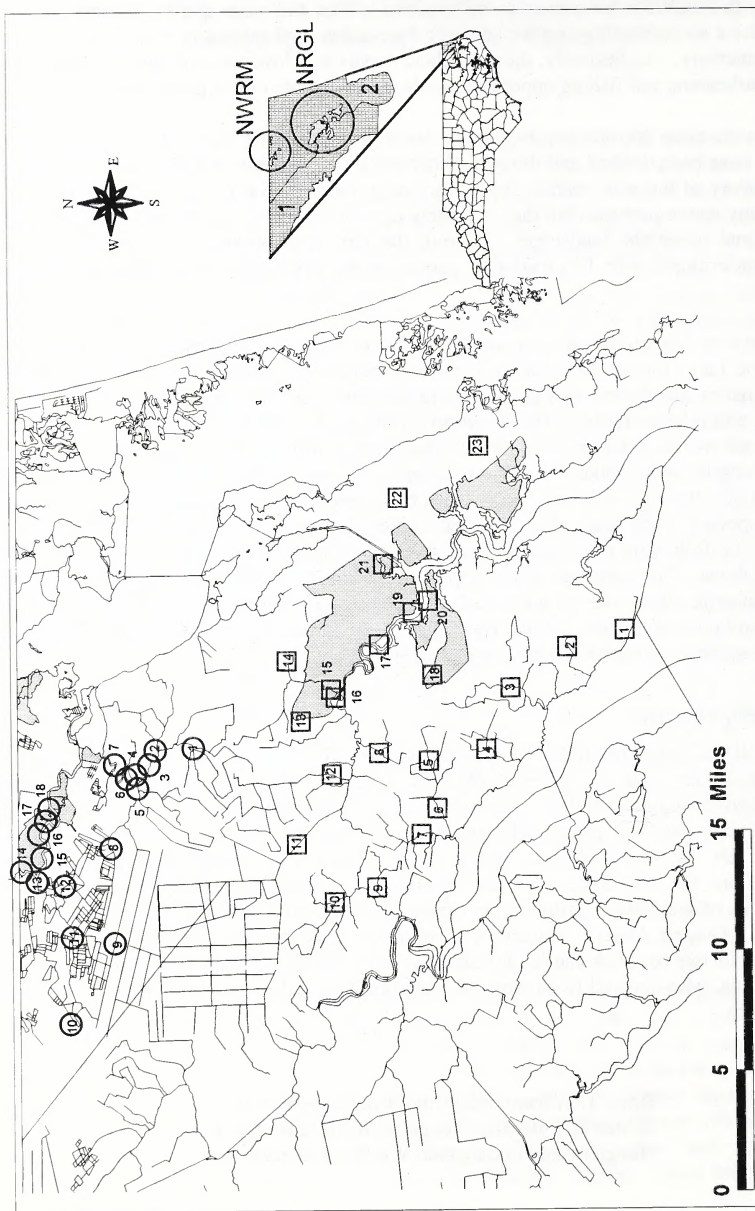


Figure 1. Map of sites surveyed during the aquatic inventories of North River Game Land (NRGL) and Northwest River Marsh Game Land (NWRM) in Camden (1) and Currituck (2) counties, North Carolina, 2000. Squares represent NRGL and circles represent NWRM. The location of the game lands within the counties, and the location of the counties within the state of North Carolina, are shown to the right.

Table 1a. Map numbers, corresponding sites surveyed, and survey effort (person-hours/electroshock seconds/minnow trap nights) for the North River Game Land aquatic inventory (indicated by squares on Figure 1).

<u>Map #</u>	<u>Site Number(s)</u>	<u>Survey Effort</u>
1	000626.4btw	0.75
2	000626.3btw	0.75
3	000626.2btw	1.0/1
4	000626.1btw	2.25/200/3
5	000627.2btw	1.5
6	000627.3btw	1.25/2
7	000627.4btw	1.5
8	000627.5btw	1.5/228
9	000815.1btw	1.75
10	000815.2btw	1.75
11	000815.3btw	1.5
12	000815.4btw	1.75
13	000627.6btw	1.5/281/1
14	000627.7btw	1.0
15	000816.3btw	1.75
16	000816.4btw	1.25
17	000816.5btw	1.5
18	000627.1btw	2.0/208
19	000816.2btw	1.25
20	000816.6btw	1.0
21	000816.1btw	1.25
22	000628.2btw	0.75/127
23	000628.1btw	1.5/105

Table 1b. Map numbers, corresponding sites surveyed, and survey effort (person-hours/electroshock seconds) for the Northwest River Marsh Game Land aquatic inventory (indicated by circles on Figure 1).

<u>Map #</u>	<u>Site Number(s)</u>	<u>Survey Effort</u>
1	000824.1btw	1.0
2	000822.1btw	1.25
3	000823.1btw	1.25
4	000822.4btw	1.0
5	000823.2btw	1.0
6	000822.3btw	1.25
7	000822.2btw	1.0
8	000824.2btw	1.25/314
9	000824.4btw	1.0
10	000824.6btw	0.5
11	000824.5btw	1.0
12	000824.3btw	0.5
13	000823.7btw	1.25
14	000823.8btw	1.0
15	000823.6btw	1.0
16	000823.5btw	1.0
17	000823.4btw	1.0
18	000823.3btw	1.25

FRESHWATER MUSSELS AND SPHAERIID CLAMS

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Introduction

The freshwater mussel fauna (Bivalvia: Unionoidea), also referred to as unionids or pearly mussels, is an intriguing, diverse, and important group of mollusks. Unionids are often prominent in macrobenthic aquatic communities where, for the most part, they are sedentary filter-feeders. Because unionids consume a major portion of the suspended particulate matter, they provide a number of important roles in aquatic ecosystems, two of which include serving as biological filters and water quality indicators. Mussels also serve as an important dietary component to a number of animals, and economically, their shells provide the nuclei used in the profitable cultured pearl industry (Theil and Fritz 1993). While not as much information has been ascertained for the sphaeriid clams (Bivalvia: Sphaeriidae), also called pea, pill, nut, or fingernail clams, they too serve an important role in aquatic ecosystems as filter-feeders. As part of the inventory of aquatic animals associated with the state-owned North River Game Land and Northwest River Marsh Game Land, we conducted field surveys of freshwater mussels and sphaeriid clams found in waterways occurring in and around the game lands to better understand the taxonomy, distribution, and conservation needs of the taxa in North Carolina.

Life History

The life cycle of freshwater mussels is an intricate process that is fairly unique when compared to that of other organisms. Spawning begins with the release of sperm from the excurrent aperture of mature males. As the sperm passively drift with the currents, they enter females through their incurrent aperture. Within sexually mature females, fertilization takes place in the suprabranchial cavity, and the resulting embryos are retained in the marsupial gills until they develop into parasitic larvae called glochidia. Glochidia are obligate parasites and must attach to suitable host fishes. Ortmann (1911) described 2 general reproductive modes for unionids based on the length of time that glochidia are retained in the gills of the female. Bradytic, or long-term brooders, typically spawn in late summer, brood young over the winter, and release mature glochidia during the following spring or early summer. Tachytic, or short-term brooders, typically spawn in the spring and release mature glochidia sometime during that summer.

Once maturity is reached, the glochidia are released into the water column through the female's excurrent aperture, from specialized gill pores, or by rupture of the ventral portion of the gill (McMahon 1991). Once released by the female, glochidia passively drift with the currents until they attach to suitable host fishes or die. Mechanisms promoting glochidia-fish contact include respiratory, feeding, and spawning activities of fishes, as well as specialized morphologies and behaviors of particular mussel species (Kraemer 1970, Dartnall and Walkey 1979, Zale and Neves 1982). Attachment occurs on the gills, fins, or scales, depending on the mussel subfamily, and is followed by encystment and metamorphosis into juveniles. Metamorphosis generally occurs over a period of 1-3 weeks (Neves 1991) but can last for a few months (Zale and Neves

1982). Once metamorphosis is complete, the juvenile mussel drops from the host fish, settles into the surrounding substrata, and, if conditions are suitable, grows until sexual maturity occurs. Then, the reproductive cycle is repeated. During a mussel's reproductive years, growth rates are reduced, since significant energy and nutrients are required to produce young.

Unlike unionids, sphaeriid clams are ovoviviparous, self-fertilizing hermaphrodites. All species brood developing embryos in specialized chambers where maternal nutrients are supplied to the embryos. After maturity is reached, the once developing embryos are released into the water column as miniature adults. Due to their relatively large size as mature embryos, compared with other freshwater bivalves (Mackie 1984), most juvenile sphaeriids disperse between drainage systems by clamping their shells onto things such as aquatic insects (McMahon 1991), feathers of waterfowl (Burky 1983), or the limbs of salamanders (Davis and Gilhen 1982) rather than dispersal by water currents. Given highly variable reproductive success rates, sphaeriids typically have 1-3 reproductive efforts per year (McMahon 1991). *Corbicula fluminea* reproduces in much the same manner as sphaeriid clams but tends to use the water currents as its primary means of dispersal (Williams and McMahon 1986). Most populations of the Asian clam have 2 reproductive efforts per year, one in the spring and the second in the late summer (McMahon 1983a).

Habitat Requirements

Freshwater mussels occur in a variety of habitat types, including both lentic (e.g., lakes, ponds, reservoirs) and lotic (e.g., rivers, streams, creeks) systems. Habitat preferences tend to be species specific, with unionids generally being most successful and prevalent in stable, coarse sand, or sand-gravel mixtures (Way et al. 1990a). Water velocity also plays a critical role in the distribution, diversity, and abundance of mussel populations. Unionids tend to thrive in conditions where water velocities are low enough to allow for substrata stability, but high enough to prevent excessive siltation (Way et al. 1990a). Water velocity also affects the amount of nutrients carried to the filter-feeding organisms. Chemical parameters such as pH and calcium concentrations can influence the distributions of mussel populations as well. The majority of species prefer alkaline water with a pH above 7.0, but unionids can grow and reproduce over a pH range of 5.6 - 8.3 and can tolerate acidic conditions as low as 4.7 (Okland and Kuiper 1982). Typically, habitats of low pH also have low calcium concentrations. Low calcium concentrations can lead to poor growth and shell dissolution in some individuals, especially if the shell is worn (Kat 1982). Given that growth and dissolution rates are affected by many factors other than pH and calcium concentrations, the minimum tolerable values can vary significantly among habitats. Another important factor to mention in the viability of freshwater mussel populations is the need for suitable host fishes. If the proper host fish is not present for a particular mussel species at any given location, then eventually this species will become extirpated from the site regardless of the habitat conditions.

Sphaeriid clams and Asian clams are generally more tolerant than unionids of what we consider to be harsh conditions. Unlike many unionids, the diversity and abundance of some *Pisidium* and *Sphaerium* species are inversely correlated with substrata size (Kilgour and Mackie 1988), which may be associated with sediment organic feeding mechanisms. *Corbicula fluminea* has a much broader substrata range, and has been seen to successfully colonize habitat consisting of bare rock outcrops to habitat with high silt loads. The highest abundances of *C. fluminea* in

North Carolina are often associated with sandy disturbed habitats or with lotic habitats below dams (J.M. Alderman, NC Wildlife Resources Commission, pers. comm.). Sphaeriids have the ability to colonize ponds and lakes where the depth is greater, the flow is negligible, and the sediment and organic loads are high. Again, this may be associated with feeding mechanisms in sphaeriid clams. Chemical parameters such as pH and calcium concentration regulate sphaeriid clams and *C. fluminea* populations in much the same manner that they affect unionid populations.

Taxonomy, Distributions, and Statuses

Freshwater mussels are represented worldwide, with North America containing the largest collection - 297 currently recognized species and subspecies (Williams et al. 1993). While unionids are distributed across the entire continent, the greatest diversity lies within the southeastern United States (Neves et al. 1997). North Carolina's share of this diversity is impressive. Once our taxonomic understanding is more complete, approximately 70 species are expected to occur in our state. A significant amount of literature describing site locations for unionids across North America has led to a more refined understanding of the distribution and taxonomy of this fauna.

Of the 297 recognized taxa of freshwater mussels in North America, Williams et al. (1993) recommended that 213 (72%) be considered endangered, threatened, or of special concern. Nearly half of North Carolina's freshwater mussel species are state listed as endangered, threatened, or special concern, and approximately 30% have undetermined statuses (J.M. Alderman, NCWRC, pers. comm.).

Sphaeriid clams are widely distributed and are represented in North America by approximately 38 species (Burch 1975, Turgeon et al. 1998). In North Carolina, there are approximately 13 species (Adams 1990). No species is currently listed at this time.

Anthropogenic effects, such as siltation, riparian habitat destruction, impoundments, pollution, and hydrologic regime alteration are negatively affecting these taxa. With the introduction of exotic species, such as *C. fluminea*, and the impending introduction of *Dreissena polymorpha* (zebra mussel), the situation continues to worsen. Therefore, it is crucial that nongame biologists continue to gather information pertaining to these organisms so proper management plans can be implemented.

Methods

The freshwater mussel and sphaeriid clam surveys of North River Game Land and Northwest River Marsh Game Land were conducted during the summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were accessed at bridge crossings or roadside access points, and sites along the North and Northwest rivers were surveyed via motorboat. Because the waterways were predominantly swamps or canals and therefore difficult to traverse, we surveyed as many habitat types as possible near the access points.

Freshwater mussels were surveyed using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). In areas where water clarity allowed, freshwater mussels were surveyed by viewing the substrata through the water surface with the naked eye. These areas also were surveyed with a view scope depending on the depth of the water. In areas that were turbid or tannic, freshwater mussels were collected by tactilely surveying suitable habitat. Freshwater mussels also were surveyed at sites by sieving the substrata through a dip net or raking the substrata. Tactile, dip net, and rake searches were the dominant survey techniques utilized due to the conditions of the waterways associated with the game lands. Any mussel specimens collected were identified to species and measured for length (mm) if possible. Brackish water bivalves and barnacles also were collected in much the same manner, and were identified according to Gosner (1978) and Porter and Houser (1997). All common and scientific nomenclature follows Turgeon et al. (1998).

Sphaeriid clams were collected using a variety of methods, including dip netting and tactile searches. The most prevalent method used was dip netting. This involved running a 1/8-inch mesh dip net through vegetation and the substrata to search for the clams. Most specimens collected were preserved in 70% ethanol and identified according to Burch (1975). Specimens also were sent to Dr. Gerald L. Mackie, University of Guelph, Ontario, Canada, for identification confirmation. All common and scientific nomenclature follows Turgeon et al. (1998).

For each taxon, a survey effectiveness score (SES) was determined at each site and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

North River Game Land

Over 5 days from 26 June to 16 August 2000, 23 sites were surveyed, and freshwater mussels were not collected or observed in any of the waterways associated with North River Game Land. The SES for mussels was 2.30. Over the same time period and sites, sphaeriid clams were observed at 15 sites (Figure 2a and Table 2a), with an overall SES score of 2.76. Five species were collected during the inventory: *Musculium partumeium* (swamp fingernailclam), *M. transversum* (long fingernailclam), *Pisidium adamsi* (Adam peaclam), *P. casertanum* (ubiquitous peaclam), and *Sphaerium occidentale* (Herrington fingernailclam). *Musculium partumeium* was the dominant sphaeriid, as it was collected from all 15 sites at which we noted pea clams. The remaining sphaeriids were collected from 4 or fewer sites. Overall, the abundance of each species varied with the swamp fingernailclam common to abundant at most sites, and the remaining 3 species rare to uncommon. Reproduction was commonly noted for *M. partumeium* and rare for the other 4 species. Most of the sphaeriids were collected from substrata comprised of detritus and silt.

In addition to the unionids and sphaeriids, a few species of brackish water organisms were collected. These species included *Rangia cuneata* (wedge rangia), *Mytilopsis leucophaeata* (dark falsemussel), and *Balanus balanoides* (northern rock barnacle) (Table 2b). All specimens

of the dark falsemussel were field identified, so it is possible that at least some of these identifications are incorrect

Northwest River Marsh Game Land

Over 3 days from 22 to 24 August, 18 sites were surveyed, and freshwater mussels were found at only 1 site (Figure 2b and Table 2c). A total of 4 live *Utterbackia imbecillis* (paper pondshell) was the only evidence of unionids in the waterways associated with the game land. All four specimens were collected from clay and silt and revealed that recent reproduction had occurred (Table 2d), with the average length at just over 16 mm. The SES for mussels was 1.36. Over the same time period and sites, sphaeriid clams were observed at 15 sites (Figure 2c and Table 2e), with an overall SES of 1.58. Six species were collected during the inventory: *Musculium partumeium* (swamp fingernailclam), *M. transversum* (long fingernailclam), *Pisidium adamsi* (Adam peaclam), *P. casertanum* (ubiquitous peaclam), *P. compressum* (ridged-beak peaclam), and *P. variable* (triangular peaclam). The swamp fingernailclam was by far the most dominant species, as it was collected from all 15 sites from which we noted pea clams. The remaining 4 species were collected from 3 or less sites. Overall, the sphaeriids were rare to uncommon and reproduction was sporadic and uncommon.

In addition to the unionids and sphaeriids, a single brackish water species was collected. This species, *Rangia cuneata* (wedge rangia), was collected from 8 sites (Table 2f).

Discussion

The overall diversity of the freshwater mussel fauna in North River Game Land and Northwest River Marsh River Game Land and their associated waterways is low. Further comparisons to other waterways within this portion of the Pasquotank River Basin are hampered due to a lack of surveys. A search of the NCWRC Nongame database did not reveal any surveys for freshwater mussels from the Pasquotank River Basin over the past 15 years. Likewise, Johnson (1970) does not list any species from the Pasquotank River Basin. However, he does list 9 species from the Chowan River Basin, which most likely encompasses the Pasquotank in his publication. *Utterbackia imbecillis* (*Anodonta imbecilis* in Johnson) is listed as residing in the Chowan River Basin, but the remaining 8 species were probably noted from areas within the Chowan River Basin where the water conditions and mussel composition were markedly different. A previous survey by the authors (Watson and Fullerton 2001) did reveal that 2 freshwater mussel species (including *Utterbackia imbecillis*) were collected from the lower portion of the Pasquotank River Basin.

Current distribution patterns and ranges of the sphaeriid fauna are much less understood than those for the freshwater mussel fauna. The location of 7 sphaeriid species is relatively high when compared to additional statewide aquatic inventories conducted by the authors. A search of the NCWRC Nongame database did not return any results from this portion of the Pasquotank River Basin for comparison. A previous survey by the authors (Watson and Fullerton 2001) did reveal that 5 of the sphaeriid clam species were collected from the lower portion of the Pasquotank River Basin.

The water body types encountered during our survey were somewhat homogeneous, with most sites representing ditches, canals, and swamps (excluding the main river reaches). Likewise, given the proximity of the survey area to the coast, most of the waterways surveyed appeared to be brackish given some of the species collected. Given the narrow range of available habitat types and the presence of brackish water, it was not surprising that we collected only a single freshwater mussel species from 1 site. Given these factors, it was somewhat surprising to find a relatively high number of sphaeriid species. However, the relative abundance and reproduction of the taxa were variable, which may have been influenced by the overall unfavorable conditions for freshwater mollusks. It also is likely that geomorphologic and topographic factors have significantly influenced the current unionid and sphaeriid fauna. Major landscape scale factors such as these are known to influence and impact the distributions and abundances of organisms over time, and it is possible that the area we surveyed has a naturally low presence of freshwater mussels and a moderate but variable presence of sphaeriid clams. While water chemistry parameters were not measured at the surveyed sites, cumulative impacts from poor land uses could be affecting the quality of the waterways. The presence of agriculture and logging within close proximity to some of the surveyed water bodies has most likely had a negative impact on stream quality through animal waste infiltration and sedimentation. The practice of ditching for drainage purposes was commonly evident and also has likely had a significant effect on the current freshwater bivalve composition of the area. With the SES ranging from 1.4 to 2.3 for freshwater mussels, it also is possible that our survey efforts somewhat influenced the poor diversity results. On the other hand, with the SES ranging from 1.6 to 2.8 for sphaeriids, it is difficult to determine if our survey efforts affected the diversity results for sphaeriid clams. However, since the sphaeriid species found in the lower portion of the Pasquotank River Basin (Watson and Fullerton 2001) were the same as found during this survey, it is unlikely that our survey efforts negatively affected the number of species collected.

While no imperiled freshwater bivalve species was collected during this survey, continual research and status surveys are needed to determine the present status of this group. *Musculium partumeium* and *Pisidium adamsi* are currently considered a species of undetermined status (Adams 1990), but recent surveys by the authors have shown this species to be common across the Coastal Plain and parts of the Piedmont. Current land management practices, including agriculture and urbanization, are having an effect on the bivalve fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

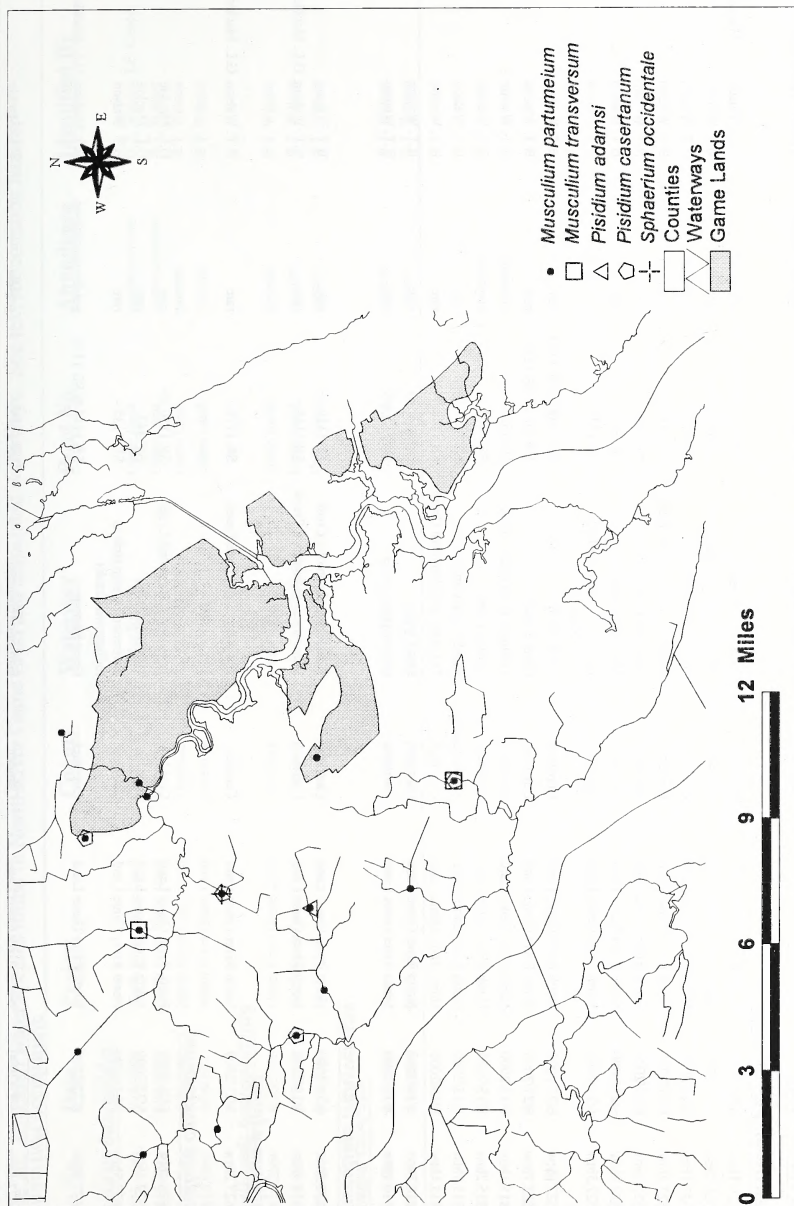


Figure 2a. Map of sites indicating where each species of sphaeriid clam was collected in the North River Game Land aquatic inventory, Camden and Currituck counties, North Carolina, 2000.

Table 2a. Sphaeriid clam species found in North River Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
<u>Musculium partumeium</u>							
000626.1bw	6/26/2000	North River Game Land	Camden	Porohok Creek	SR 1111 (1110) +	abundant	B.T. Watson, G.L. Mackie
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	common	B.T. Watson
000627.1bw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	common	B.T. Watson
000627.2bw	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	common	B.T. Watson
000627.3bw	6/27/2000	North River Game Land	Camden	Areneuse Creek	NC 343	rare	B.T. Watson
000627.4bw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	rare	B.T. Watson
000627.5bw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (trib to Indiantown Creek)	SR 1135 -	uncommon	B.T. Watson
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	rare	B.T. Watson
000627.7bw	6/27/2000	North River Game Land	Currituck	Great Swamp	US 158 @ SR 1246	rare	B.T. Watson
000815.1bw	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	common	B.T. Watson
000815.2bw	8/15/2000	North River Game Land	Camden	Sawyer Creek	SR 1203 +	common	B.T. Watson
000815.3bw	8/15/2000	North River Game Land	Camden/Currituck	Run Swamp Canal	NC 34 -	rare	B.T. Watson
000815.4bw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	rare	B.T. Watson
000816.3bw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	rare	B.T. Watson
000816.4bw	8/16/2000	North River Game Land	Currituck	North River	Game Land	rare	B.T. Watson
<u>Musculium transversum</u>							
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	rare	B.T. Watson
000815.4bw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	rare	B.T. Watson, G.L. Mackie
<u>Pisidium adamsi</u>							
000627.2bw	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	rare	B.T. Watson, G.L. Mackie
<u>Pisidium casertanum</u>							
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	rare	G.L. Mackie
000627.4bw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	rare	G.L. Mackie
000627.5bw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (trib to Indiantown Creek)	SR 1135 -	rare	B.T. Watson
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	patchy uncommon	B.T. Watson, G.L. Mackie
<u>Sphaerium occidentale</u>							
000627.5bw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp	SR 1135 -	present	G.L. Mackie

Table 2b. Brackish water species found in North River Game Land and associated waterways. See text for common names.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<i>Balanus balanoides</i>							
000816.1btw	8/16/2000	North River Game Land	Currituck	Taylor Bay	Game Land	patchy common	B.T. Watson, J.E. Cooper
000816.2btw	8/16/2000	North River Game Land	Currituck	North River	Game Land	patchy common	B.T. Watson
000816.5btw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	present	B.T. Watson
000816.6btw	8/16/2000	North River Game Land	Currituck	North River	Game Land	present	B.T. Watson
<i>Mytilopsis leucophaeata</i>							
000816.2btw	8/16/2000	North River Game Land	Currituck	North River	Game Land	present	B.T. Watson
000816.5btw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	present	B.T. Watson
000816.6btw	8/16/2000	North River Game Land	Currituck	North River	Game Land	present	B.T. Watson
<i>Rangia cuneata</i>							
000816.5btw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	present	B.T. Watson
000816.6btw	8/16/2000	North River Game Land	Currituck	North River	Game Land	present	B.T. Watson

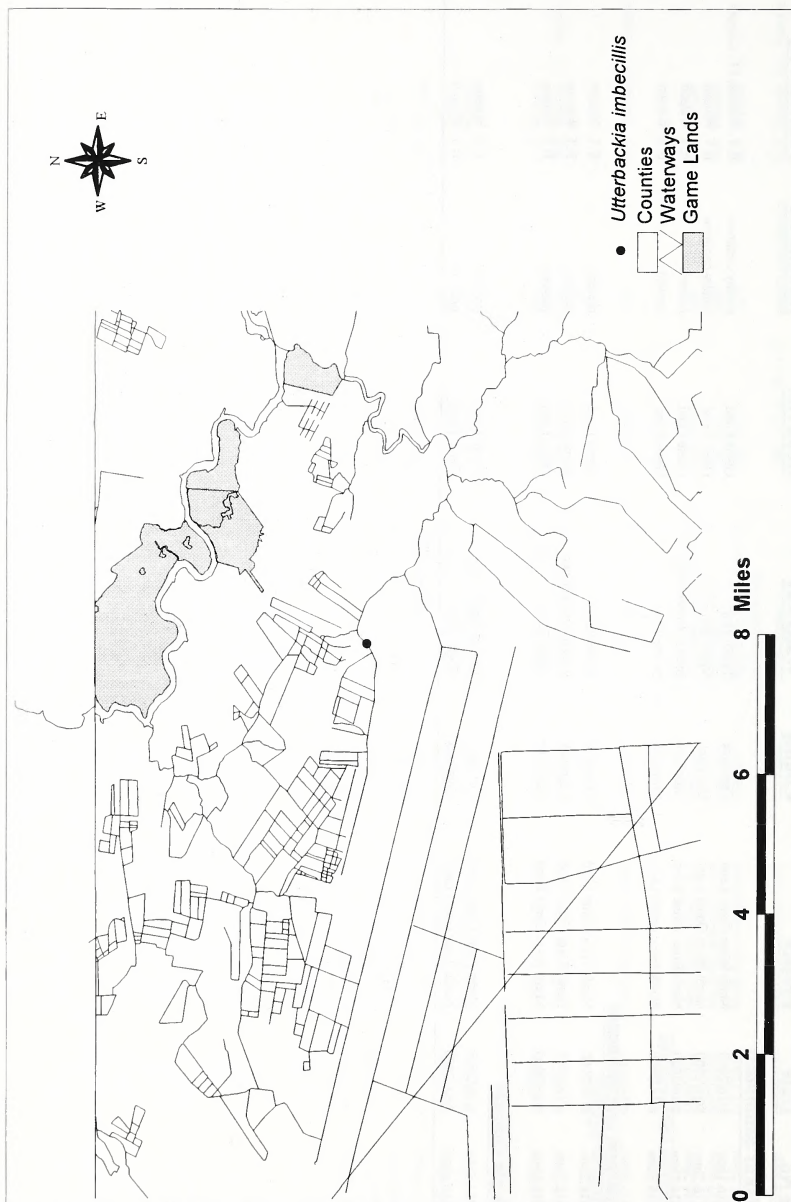


Figure 2b. Map of sites indicating where each species of freshwater mussel was collected in the Northwest River Marsh Game Land aquatic inventory, Currituck County, North Carolina, 2000.

Table 2c. Freshwater mussel species found in Northwest River Marsh Game Land and associated waterways. See text for common names.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<i>Utterbackia imbecillis</i>							
000824.2bww	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	present	B.T. Watson

Table 2d. Statistics on valve lengths of live freshwater mussels found in Northwest River Marsh Game Land and associated waterways.
See text for common names.

<i>Utterbackia imbecillis</i>	Avg	Std	Min	Max
live (4 records)	16.3	8.2	6.0	26.0
Species Total (4 records)	16.3	8.2	6.0	26.0

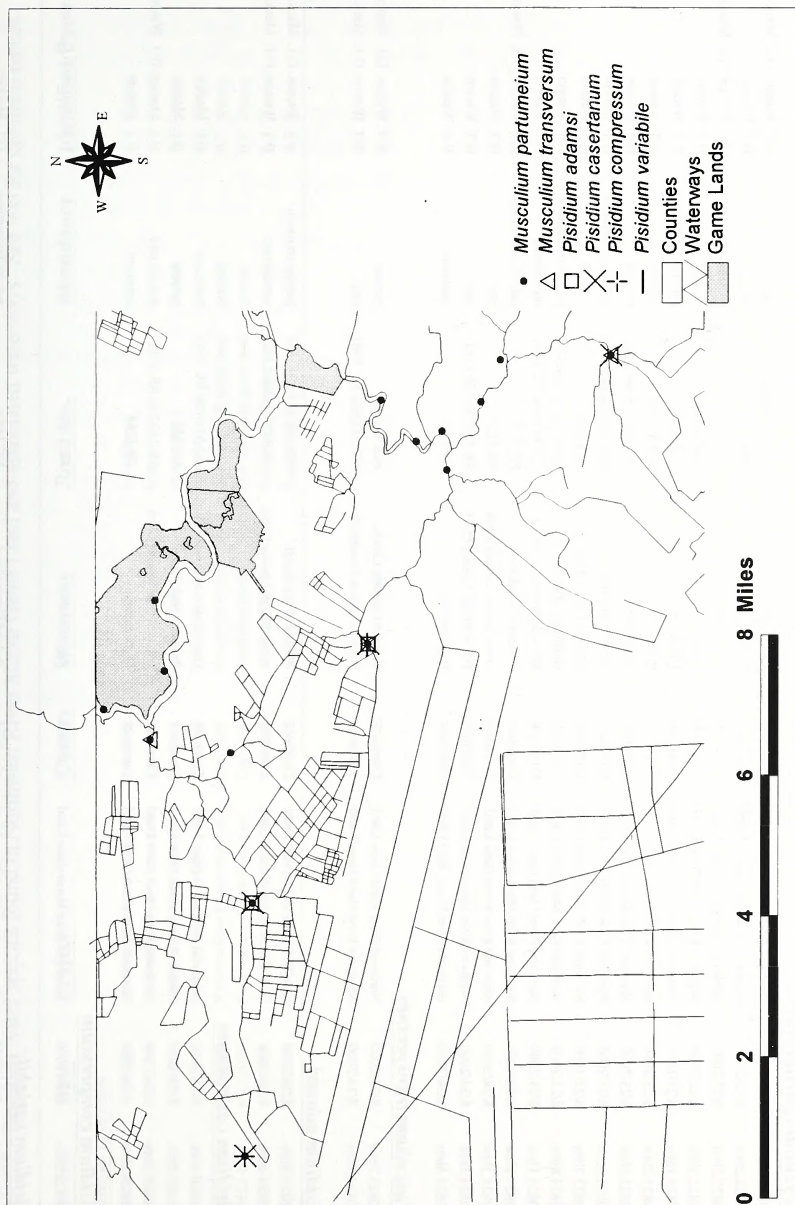


Figure 2c. Map of sites indicating where each species of sphaeriid clam was collected in the Northwest River Marsh Game Land aquatic inventory, Camden and Currituck counties, North Carolina, 2000.

Table 2e. Sphaeriid clam species found in Northwest River Marsh Game Land and associated waterways. See text for common names.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<i>Musculium partumeium</i>							
000822.1btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	SR 1232 (boat access)	rare	B.T. Watson, G.L. Mackie
000822.2btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	rare	B.T. Watson
000822.3btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson, G.L. Mackie
000822.4btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Canal to Tull Creek	boat access	present	B.T. Watson
000823.1btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	patchy uncommon	B.T. Watson
000823.2btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	common	B.T. Watson
000823.3btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.6btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	patchy uncommon	B.T. Watson
000823.7btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson
000823.8btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	patchy uncommon	B.T. Watson
000824.1btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	uncommon	B.T. Watson
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	patchy uncommon	B.T. Watson, G.L. Mackie
000824.3btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Creek	SR 1222 -	rare	B.T. Watson
000824.5btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Creek	SR 1227 @ SR 1313 -	rare	B.T. Watson
000824.6btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Light Swamp	SR 1218	common	B.T. Watson
<i>Musculium transversum</i>							
000823.7btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson, G.L. Mackie
000824.1btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	rare	B.T. Watson, G.L. Mackie
<i>Pisidium adamsi</i>							
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	patchy common	B.T. Watson, G.L. Mackie
000824.5btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Creek	SR 1227 @ SR 1313 -	patchy rare	B.T. Watson, G.L. Mackie
<i>Pisidium casertanum</i>							
000824.1btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	rare	G.L. Mackie
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	present	G.L. Mackie
000824.5btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Creek	SR 1227 @ SR 1313 -	patchy rare	G.L. Mackie, B.T. Watson
000824.6btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Light Swamp	SR 1218	common	B.T. Watson
<i>Pisidium compressum</i>							
000824.6btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Light Swamp	SR 1218	present	B.T. Watson, G.L. Mackie
<i>Pisidium variable</i>							
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	patchy uncommon	G.L. Mackie

Table 2f. Brackish water species found in Northwest River Marsh Game Land and associated waterways. See text for common names.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<i>Rangia cuneata</i>							
000822.2btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000822.3btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000822.4btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Canal to Tull Creek	boat access	present	B.T. Watson
000823.1btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	common	B.T. Watson
000823.3btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.4btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.5btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.6btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson

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AQUATIC SNAILS

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Introduction

Freshwater snails (Mollusca: Gastropoda) are among the most ubiquitous organisms of shallow littoral zones in lakes and streams. Due to their behavior, widespread distribution, and commonly high abundance, snails serve a number of important roles in aquatic ecosystems. These include driving predator-prey interactions (Vermeij and Covich 1978, Lodge et al. 1987), serving as a dietary component to fish and wildlife, acting as water quality indicators, and most importantly, grazing on nuisance algae and detritus. However, freshwater snails are often overlooked in part due to their small size, perceived lack of charisma, cryptic habits, and the lack of readily available comprehensive guides for identification. As part of the inventory of aquatic animals associated with the state-owned North River Game Land and Northwest River Marsh Game Land, we conducted field surveys of aquatic snails found in waterways occurring in and around the game lands to better understand the taxonomy, distribution, and conservation needs of the taxa in North Carolina.

Life History

Much information about the reproductive cycles of freshwater snails has been ascertained due to the ease of laboratory rearing. From this information, 2 typical categories have been developed in which snails can be placed reproductively (Russell-Hunter 1978, Calow 1978). The first category includes annual adults that reproduce in the spring and die (semelparous). Most pulmonates (lung breathing), which are oviparous hermaphrodites, belong to this group including the genera *Lymnaea* and *Physa*. The second category includes perennial adults that reproduce in both spring and late summer. Most prosobranchs (gill breathing), which are dioecious and can be oviparous or ovoviviparous, belong to this group. These species are iteroparous and often live and reproduce for 4-5 years. Prosobranchs also are often sexually dimorphic, with females living longer than males (Brown et al. 1989).

Habitat and Food Requirements

Freshwater snails occupy a variety of habitat types, including both lentic (e.g., lakes, ponds, reservoirs) and lotic (e.g., rivers, streams, creeks) systems. Habitat preferences tend to be species specific, with well-documented substratum selection (Brown 1991). In general, silty habitats with slow-moving currents are colonized predominately by pulmonates or detritivorous prosobranchs, whereas limpets or prosobranch grazers colonize fast-current localities (Harman 1972). Many biotic and abiotic factors regulate the distribution of freshwater snails, with water hardness and pH considered to be the major determinants (Macan 1950, Pip 1986). However, it has been suggested that physiochemical factors such as calcium concentrations may only act to limit successful invasion of habitats with extreme levels of these factors (Lodge et al. 1987).

Other factors such as dispersal ability and adequate substrata may play a more prominent role in snail distribution.

Freshwater snails are predominantly herbivores or detritivores, although they can ingest carrion (Bovbjerg 1968) or passively consume small invertebrates associated with periphyton (Cuker 1983a). Apparently, they prefer periphyton because it is easier to scrape than macrophytes, and it contains higher concentrations of nitrogen and other limiting nutrients (Russell-Hunter 1978, Aldridge 1983). Algae and diatoms also are prominent sources of nutrients for freshwater snails (Lodge 1986). While macrophytes are not the preferred source of nutrients for most freshwater snails, significant consumption can occur if snail densities reach high levels (Sheldon 1987).

Taxonomy, Distribution, and Statuses

Freshwater snails are divided into 2 groups – prosobranchs and pulmonates. Prosobranch snails are gill breathing and have a calcareous plate called an operculum that seals the aperture when the snail withdraws into its shell. Pulmonate snails are lung breathing and lack an operculum. Of the approximately 500 species recognized in North America, there are 49 genera and 349 species of prosobranch snails and 29 genera and 150 species of pulmonate snails (Burch 1982). While snails are widespread across the continent, they have reached their greatest abundance and diversity within the streams of the southeastern United States (Brown 1991). In North Carolina, there are approximately 52 species representing 10 families (Bogan 1997). Since very little work has been done to monitor freshwater snail populations, the current status of many species within North Carolina is undetermined. It is unknown as to the magnitude of impact that anthropogenic effects such as siltation, riparian habitat destruction, impoundments, pollution, and hydrologic regime alteration have had on the state's snail fauna. Therefore, it is crucial that nongame biologists continue to gather information pertaining to these organisms so proper management plans can be implemented.

Methods

The aquatic snail surveys of North River Game Land and Northwest River Marsh Game Land were conducted during the summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were accessed at bridge crossings or roadside access points, and sites along the North and Northwest rivers were surveyed via motorboat. Because the waterways were predominantly swamps or canals and therefore difficult to traverse, we surveyed as many habitat types as possible near the access points.

Freshwater snails were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). The most common methods used to sample the snail fauna were visual searches and dip netting. The visual search basically involved examining rocky substrata, woody debris, vegetation, cans and bottles, and other items that snails might colonize. Dip netting involved running a 1/8-inch mesh dip net through vegetation and the substrata to collect snails. Other techniques used to collect snails included tactile searches, the use of a viewscope, and raking of the substrata. Habitat preference, relative abundance, and recent reproduction for snail species were noted at each site. Snails were preserved in 70% ethanol and identified according to Burch (1989) and Basch (1963). Scientific

names are according to Turgeon et al. (1998). Dr. Arthur E. Bogan, curator of aquatic invertebrates at the NC State Museum of Natural Sciences, verified some of the species identifications. Not all snails collected were preserved for obvious conservation and ethical reasons.

For aquatic snails, a survey effectiveness score (SES) was determined at each site and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

North River Game Land

Over 5 days from 26 June to 16 August 2000, 23 sites were surveyed, and aquatic snails were collected or observed at 21 localities (Figures 3a-c). At least 9 species representing 5 families were documented during the North River Game Land survey (Tables 3a and 3b). Due to the difficulty of identifying hydrobiids (see Discussion), we have identified all specimens to family for this report. The relative abundance of each species varied, but a number of species were well distributed over the survey area. These species included *Physella* sp., *Micromenetus dilatatus*, and *Ferrissia* sp., which were present at 15, 15, and 13 sites, respectively (Figures 3a-c). Similarly, *Pseudosuccinea columella* and *Planorbella trivolvis* were fairly common with representation at 12 and 10 sites, respectively. Due to species level variation and the uncertainty of positively discerning *Ferrissia* specimens, all specimens of this genus were identified as *Ferrissia* sp. Likewise, all *Physella* specimens were identified to genus only, since the soft parts were not examined. The remaining snail species were represented over a smaller number of sites, ranging from 1-4. Regardless of the number of sites from which a particular species was collected, abundances were typically variable among sites, ranging predominantly from rare to uncommon. Recent reproduction was seen at a number of sites for most of the snail species collected during the survey, but it was highly variable and inconsistent. Due to the minute size of some of the species (e.g., *Micromenetus dilatatus* and Hydrobiidae), it was difficult to confirm whether these were adults or juveniles, and typically reproduction was not recorded. The SES for aquatic snails was 2.78.

Ferrissia sp., *Laevapex fuscus* (dusky ancyloid), *Micromenetus dilatatus* (bugle sprite), and *Gyraulus deflectus* (flexed gyro) were typically found in areas with slow to moderate flow on aquatic vegetation, woody debris, and detritus. These species also were found on cans and bottles, with the ancylicids being especially common on these items.

Physella sp. (physa snail), *Pseudosuccinea columella* (mimic lymnaea), *Planorbella trivolvis* (marsh rams-horn), and *Planorbula armigera* (thicklip rams-horn) also tended to inhabit areas with slow to moderate flow, which included backwater areas, along the banks or edges of waterways, or wherever the conditions were swamp-like. *Physella* sp. and *P. columella* typically were found on aquatic vegetation and woody debris, while occasionally residing along clay and mud banks. The rams-horns were typically associated with detritus and vegetation in stagnant and backwater areas.

Hydrobiids were collected from areas ranging from swamp-like to run-like flow. Specimens tended to be common on woody debris but also were collected from detritus and vegetation.

Northwest River Marsh Game Land

Over 3 days from 22 to 24 August, 18 sites were surveyed, and aquatic snails were collected or observed at all 18 localities (Figures 3d-f). At least 10 species representing 5 families were documented during the Northwest River Marsh Game Land survey (Tables 3c and 3d). Due to the difficulty of identifying hydrobiids (see Discussion), we have identified all specimens to family for this report. The relative abundance of each species varied, but a few of species were well distributed over the survey area. These species included *Micromenetus dilatatus*, *Pseudosuccinea columella*, and *Physella* sp., which were present at 15, 13, and 12 sites, respectively (Figures 3d-f). Due to species level variation and the uncertainty of positively discerning *Physella* specimens, all specimens of this genus were identified as *Physella* sp., since soft parts were not examined. Likewise, all *Ferrissia* specimens were identified to genus only. The remaining snail species were represented over a smaller number of sites, ranging from 1-7. Regardless of the number of sites from which a particular species was collected, abundances were typically rare to uncommon or listed as present, since we felt we could not accurately determine a relative abundance. Recent reproduction was seen at a number of sites for most the snail species collected during the survey, but it was highly variable and inconsistent. Due to the minute size of some of the species (e.g., *Micromenetus dilatatus* and Hydrobiidae), it was difficult to confirm whether these were adults or juveniles, and typically reproduction was not recorded. The SES for aquatic snails was 1.64.

Ferrissia sp., *Laevapex fuscus* (dusky ancyloid), *Micromenetus dilatatus* (bugle sprite), and *Gyraulus deflectus* (flexed gyro) were typically found in areas with slow to moderate flow on aquatic vegetation, detritus, and woody debris. These species also were found on cans and bottles, with the ancylicids being especially common on these items.

Physella sp. (physa snail), *Pseudosuccinea columella* (mimic lymnaea), *Planorbella duryi* (Seminole rams-horn), *Planorbella trivolvis* (marsh rams-horn), and *Planorbula armigera* (thicklip rams-horn) also tended to inhabit areas with slow to moderate flow, which included backwater areas, along the bank and edges of waterways, behind sandbars, or wherever the conditions were swamp-like. *Physella* sp. and *P. columella* typically were found on aquatic vegetation and woody debris, while occasionally residing along the clay and mud banks. The rams-horns were typically associated with detritus and vegetation in stagnant, backwater areas, and ditches and canals.

Hydrobiids were collected from areas ranging from swamp-like to run-like flow. Specimens tended to be common on woody debris but also were collected from detritus and vegetation.

Discussion

Overall, the diversity and abundance of freshwater snails in the waterways associated with the North River Game Land and the Northwest River Marsh Game Land appear to be moderate to high. The results reported here are typical of additional state-wide aquatic inventories conducted

by the authors. Further comparisons are hampered due to a lack of survey information for the upper portion of the Pasquotank River Basin. However, a recent aquatic survey conducted by the authors in the lower portion of the Pasquotank River Basin (Watson and Fullerton 2001) resulted in 11 aquatic snail species, 9 of which were documented during this survey. Given the relative diversity of habitat types and flow regimes encountered, it was surprising that we found a relatively healthy number of gastropod species. However, these factors may have been the primary dynamic contributing to the limited distribution, low abundance, and poor reproduction for a fair number of the species. It also is likely that geomorphologic and topographic factors have significantly influenced the current gastropod fauna. Major landscape scale factors such as these are known to influence and impact the distribution and abundance of organisms over time. While water chemistry parameters were not measured at the surveyed sites, cumulative impacts from poor land uses could be affecting the quality of the waterways. The presence of agriculture and logging within close proximity to some of the surveyed water bodies has most likely had a negative impact on stream quality through animal waste infiltration and sedimentation. Effects from urbanization were minimal, since most of the river basin is rural. The practice of ditching for drainage purposes was commonly evident in some areas and also has likely had a significant effect on the current freshwater bivalve composition of the area. These land use impacts may have been the primary dynamic contributing to some of the species' limited distributions and their relatively low abundances. Since the SES varied highly between the 2 game lands, our survey efforts may have been insufficient to give an accurate reflection of the aquatic snail composition and health of the area.

Taxonomic uncertainties within the freshwater snail fauna make the results here subject to revision. For example, the differentiation between *F. rivularis* and *F. fragilis* is difficult due to shell shape variation. Therefore, a common factor used to distinguish these species is the habitat they are collected in, with *F. rivularis* colonizing rivers and streams and *F. fragilis* inhabiting stagnant areas such as ditches, ponds, and backwater areas (Burch 1989). All of the limpets identified in this survey were assigned to *Ferrissia* sp., but it is possible that at least both species inhabit some of the sites that were surveyed. Some of the *Ferrissia* sp. field identifications could also have been *Laevapex fuscus* given the difficulty in sometimes differentiating smaller specimens in the field. Likewise, many uncertainties exist as to the taxonomy of *Physella* and hydrobiids without examination of soft parts (Burch 1989). Since we did not preserve the specimens for the examination of soft parts, we identified *Physella* specimens to genus only and hydrobiid specimens to family. Examination of the shell characteristics of the hydrobiid specimens leads us to believe that they belong to the genera *Gillia* or *Ammicola* (or both). Additionally, the widespread distribution and small size of *Micromenetus dilatatus* make it very easy to field misidentify similar species as the bugle sprite. Therefore, *Gyraulus deflectus* may have been misidentified at a number of sites reducing its presence and range.

The collection of *Planorbella duryi* in the upper Pasquotank River Basin is significant, as these are additional records of the exotic within North Carolina (Watson and Fullerton 2001). The historical distribution of this species is described as extending from northern to southern Florida (Burch 1989). It is believed this species was introduced through the aquaria trade (A.E. Bogan, NCSM, pers. comm.). On a past trip to a local aquarium shop, Bogan viewed specimens of the Seminole rams-horn on aquatic vegetation that had been shipped from Florida. However, it is possible that the specimens we have identified as

P. duryi are actually *Planorbella trivolvis*. Baker (1945) shows a photograph of an aquarium raised marsh rams-horn that looks like the Seminole rams-horn, and comments on their similarity.

While no threatened or endangered gastropod species was collected during the survey of North River and Northwest River Marsh game lands, continual research and status surveys are needed to determine the present status of each species. The status of *Gyraulus deflectus* is considered possibly imperiled but undetermined due to a lack of information (Adams 1990), which may be in part due to misidentification of the species given its small size and similarity to other planorbids. Current land management practices, including agriculture and urbanization, are having an effect on the snail fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

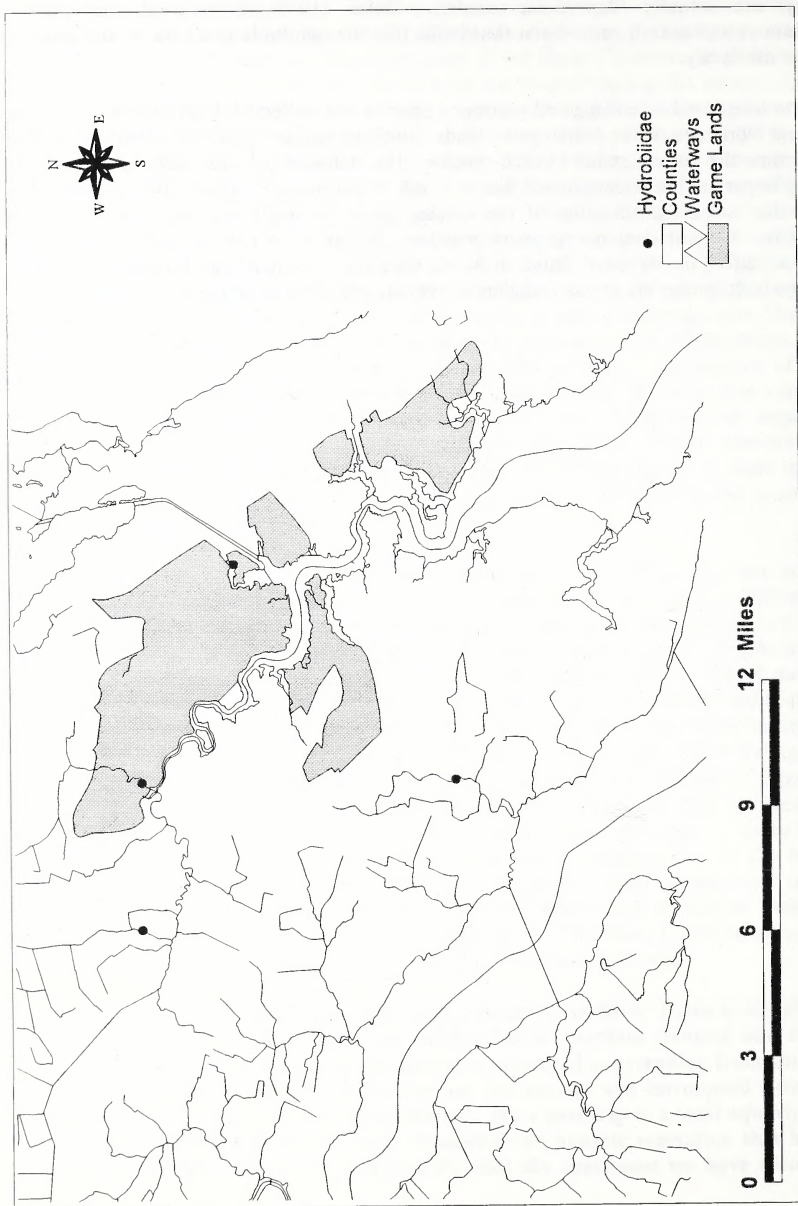


Figure 3a. Map of sites indicating where each species of prosobranch snail was collected in the North River Game Land aquatic inventory, Camden and Currituck counties, North Carolina, 2000.

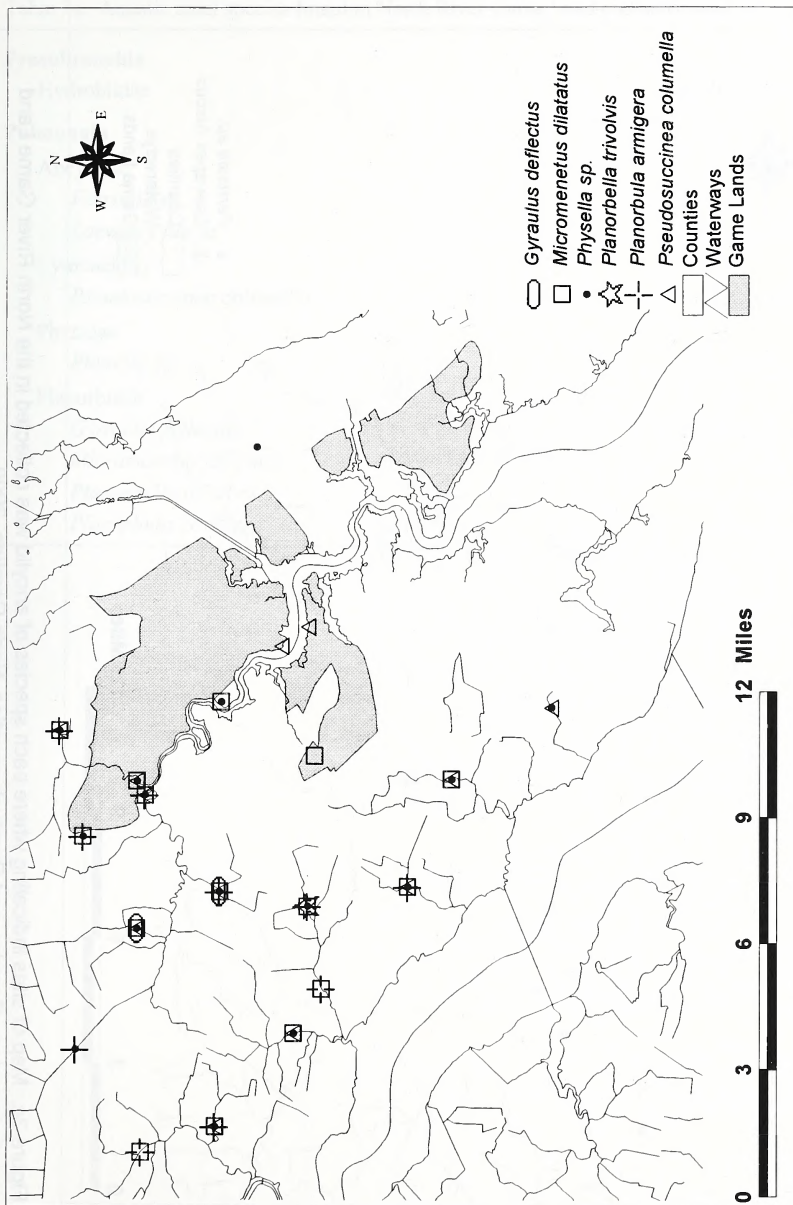


Figure 3b. Map of sites indicating where each species of pulmonate snail was collected in the North River Game Land aquatic inventory, Camden and Currituck counties, North Carolina, 2000.

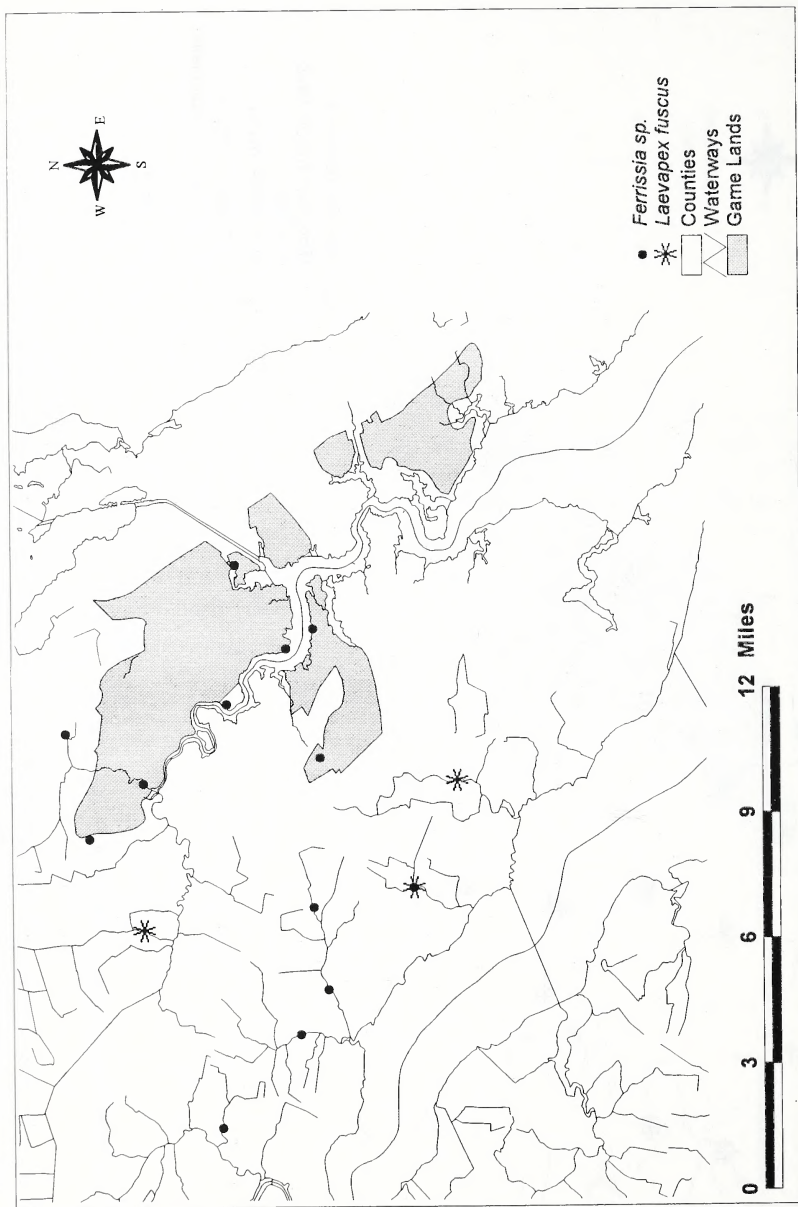


Figure 3c. Map of sites indicating where each species of ancylid was collected in the North River Game Land aquatic inventory, Camden and Currituck counties, North Carolina, 2000.

Table 3a. Aquatic snail species found in North River Game Land and associated waterways.

Prosobranchia

Hydrobiidae

hydrobiid

Pulmonata

Ancylidae

Ferrissia sp.

limpet

Laevapex fuscus

dusky ancylid

Lymnaeidae

Pseudosuccinea columella

mimic lymnaea

Physidae

Physella sp.

physa snail

Planorbidae

Gyraulus deflectus

flexed gyro

Micromenetus dilatatus

bugle sprite

Planorbella trivolvis

marsh rams-horn

Planorbula armigera

thicklip rams-horn

Table 3b. Aquatic snail species found in North River Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
<i>Ferrissia sp.</i>							
000626.1bw	6/26/2000	North River Game Land	Camden	Portohonk Creek	SR 1111 (1110) +	rare	B. T. Watson
000627.1bw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	patchy uncommon	B. T. Watson
000627.2bw	6/27/2000	North River Game Land	Camden	Tributary to Arenouse Creek	SR 1119 +	rare	B. T. Watson
000627.3bw	6/27/2000	North River Game Land	Camden	Arenouse Creek	NC 343	patchy common	B. T. Watson
000627.4bw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	rare	B. T. Watson
000627.5bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	rare	B. T. Watson
000627.7bw	6/27/2000	North River Game Land	Currituck	Great Swamp	US 158 @ SR 1246	rare	B. T. Watson
000815.1bw	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	rare	B. T. Watson
000816.1bw	8/16/2000	North River Game Land	Currituck	Taylor Bay	Game Land	uncommon	B. T. Watson
000816.2bw	8/16/2000	North River Game Land	Currituck	North River	Game Land	patchy rare	B. T. Watson
000816.3bw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	present	B. T. Watson
000816.5bw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	patchy uncommon	B. T. Watson
000816.6bw	8/16/2000	North River Game Land	Currituck	North River	Game Land	patchy uncommon	B. T. Watson
<i>Gyrulus deflectus</i>							
000627.5bw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (Trib to Indiantown Creek)	SR 1135 -	rare	B. T. Watson
000815.4bw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	common	B. T. Watson
<i>Hydrobiidae</i>							
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	patchy uncommon	B. T. Watson
000815.4bw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	rare	B. T. Watson
000816.1bw	8/16/2000	North River Game Land	Currituck	Taylor Bay	Game Land	patchy rare	B. T. Watson, A.E. Bogan
000816.3bw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	rare	B. T. Watson
<i>Laevapex fuscus</i>							
000626.1bw	6/26/2000	North River Game Land	Camden	Portohonk Creek	SR 1111 (1110) +	rare	B. T. Watson
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	rare	B. T. Watson
000815.4bw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	rare	B. T. Watson

Table 3b (cont.). Aquatic snail species found in North River Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<i>Micromenetus dilatatus</i>							
000626.1btw	6/26/2000	North River Game Land	Camden	Potohok Creek	SR 1111 (1110) +	patchy common	B.T. Watson
000626.2btw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 +/-	patchy uncommon	B.T. Watson
000627.1btw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	uncommon	B.T. Watson
000627.2btw	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	patchy uncommon	B.T. Watson
000627.3btw	6/27/2000	North River Game Land	Camden	Areneuse Creek	NC 343	patchy common	B.T. Watson
000627.4btw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	patchy uncommon	B.T. Watson
000627.5btw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (Trib to Indiantown Creek)	SR 1135 -	patchy uncommon	B.T. Watson
000627.6btw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	patchy uncommon	B.T. Watson
000627.7btw	6/27/2000	North River Game Land	Currituck	Great Swamp	US 158 @ SR 1246	rare	B.T. Watson
000815.1btw	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	rare	B.T. Watson
000816.1btw	8/15/2000	North River Game Land	Camden	Sawyer Creek	SR 1203 +	rare	B.T. Watson
000815.4btw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	rare	B.T. Watson
000816.3btw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	rare	B.T. Watson
000816.4btw	8/16/2000	North River Game Land	Currituck	North River	Game Land	patchy rare	B.T. Watson
000816.5btw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	patchy uncommon	B.T. Watson
<i>Physella sp.</i>							
000626.1btw	6/26/2000	North River Game Land	Camden	Potohok Creek	SR 1111 (1110) +	patchy uncommon	B.T. Watson
000626.2btw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 +/-	patchy uncommon	B.T. Watson
000626.3btw	6/26/2000	North River Game Land	Camden	Tributary to Pasquotank River	SR 1100	patchy common	B.T. Watson
000627.2btw	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	patchy uncommon	B.T. Watson
000627.4btw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	rare	B.T. Watson
000627.5btw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (Trib to Indiantown Creek)	SR 1135 -	rare	B.T. Watson
000627.6btw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	patchy uncommon	B.T. Watson
000627.7btw	6/27/2000	North River Game Land	Currituck	Great Swamp	US 158 @ SR 1246	rare	B.T. Watson
000628.2btw	6/28/2000	North River Game Land	Currituck	Maple Swamp	SR 1140	localized abundant	B.T. Watson
000815.1btw	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	rare	B.T. Watson
000815.3btw	8/15/2000	North River Game Land	Camden	Run Swamp Canal	NC 34 -	uncommon	B.T. Watson
000815.4btw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	rare	B.T. Watson
000816.3btw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	rare	B.T. Watson
000816.4btw	8/16/2000	North River Game Land	Currituck	North River	Game Land	rare	B.T. Watson
000816.5btw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	rare	B.T. Watson

Table 3b (cont.). Aquatic snail species found in North River Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<u>Planorbella sp.</u>							
000627.2bww	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	present	B.T. Watson, A.E. Bogan
<u>Planorbella trivolvis</u>							
000627.2bww	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	abundant	B.T. Watson
<u>Planorbula armigera</u>							
000626.1bww	6/26/2000	North River Game Land	Camden	Portohok Creek	SR 1111 (1110) +	rare	B.T. Watson
000627.7bww	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	common	B.T. Watson
000627.3bww	6/27/2000	North River Game Land	Camden	Areneuse Creek	NC 343	rare	B.T. Watson
000627.5bww	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (Trib to Indiantown Creek)	SR 1135 -	patchy uncommon	B.T. Watson
000627.6bww	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	rare	B.T. Watson
000627.7bww	6/27/2000	North River Game Land	Currituck	Great Swamp	US 158 @ SR 1246	uncommon	B.T. Watson
000815.1bww	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	uncommon	B.T. Watson
000815.2bww	8/15/2000	North River Game Land	Camden	Sawyer Creek	SR 1203 +	rare	B.T. Watson
000815.3bww	8/15/2000	North River Game Land	Camden/Currituck	Run Swamp Canal	NC 34 -	common	B.T. Watson
000816.4bww	8/16/2000	North River Game Land	Currituck	North River	Game Land	rare	B.T. Watson
<u>Pseudosuccinea columella</u>							
000626.1bww	6/26/2000	North River Game Land	Camden	Portohok Creek	SR 1111 (1110) +	rare	B.T. Watson
000626.2bww	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 +/-	patchy uncommon	B.T. Watson
000626.3bww	6/26/2000	North River Game Land	Camden	Tributary to Pasquotank River	SR 1100	patchy common	B.T. Watson
000627.4bww	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	rare	B.T. Watson
000627.5bww	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (Trib to Indiantown Creek)	SR 1135 -	rare	B.T. Watson
000627.7bww	6/27/2000	North River Game Land	Currituck	Great Swamp	US 158 @ SR 1246	uncommon	B.T. Watson
000815.1bww	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	rare	B.T. Watson
000815.4bww	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	rare	B.T. Watson
000816.2bww	8/16/2000	North River Game Land	Currituck	North River	Game Land	patchy common	B.T. Watson
000816.3bww	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	rare	B.T. Watson
000816.4bww	8/16/2000	North River Game Land	Currituck	North River	Game Land	patchy uncommon	B.T. Watson
000816.6bww	8/16/2000	North River Game Land	Currituck	North River	Game Land	patchy uncommon	B.T. Watson

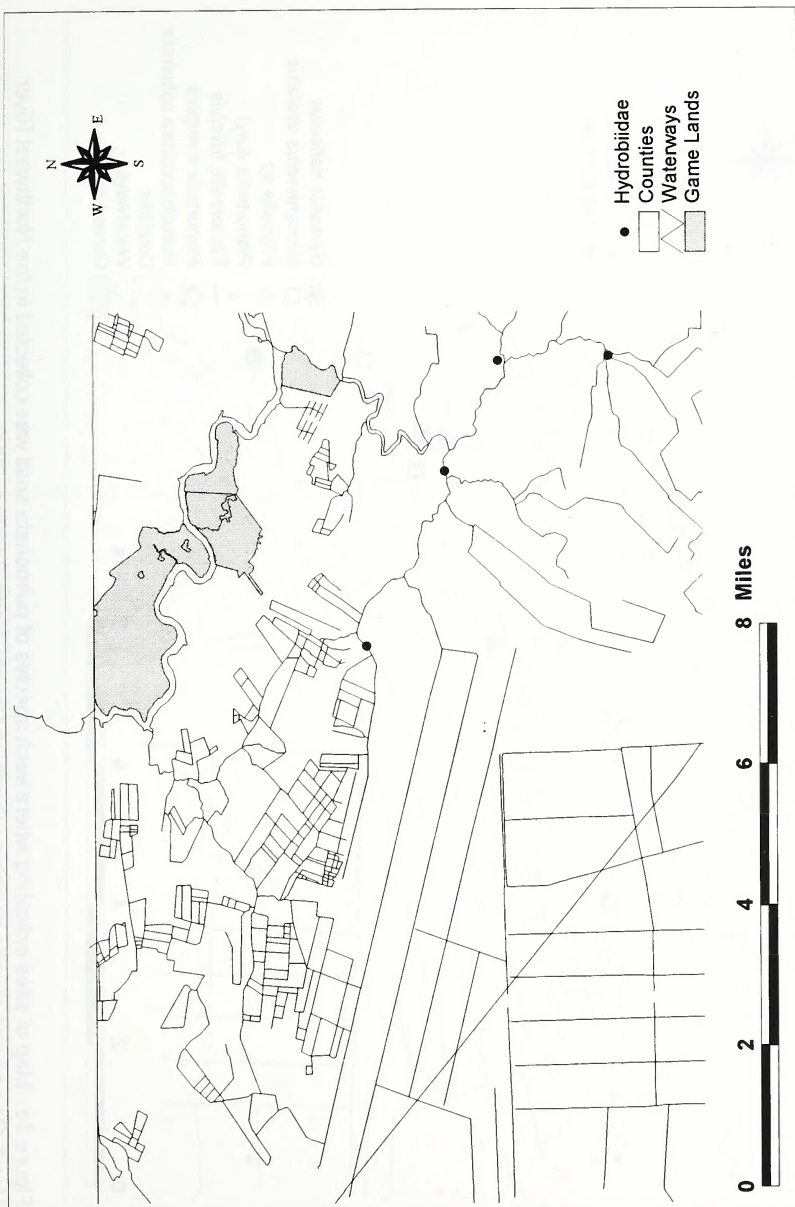


Figure 3d. Map of sites indicating where each species of prosobranch snail was collected in the Northwest River Marsh Game Land aquatic inventory, Currituck County, North Carolina, 2000.

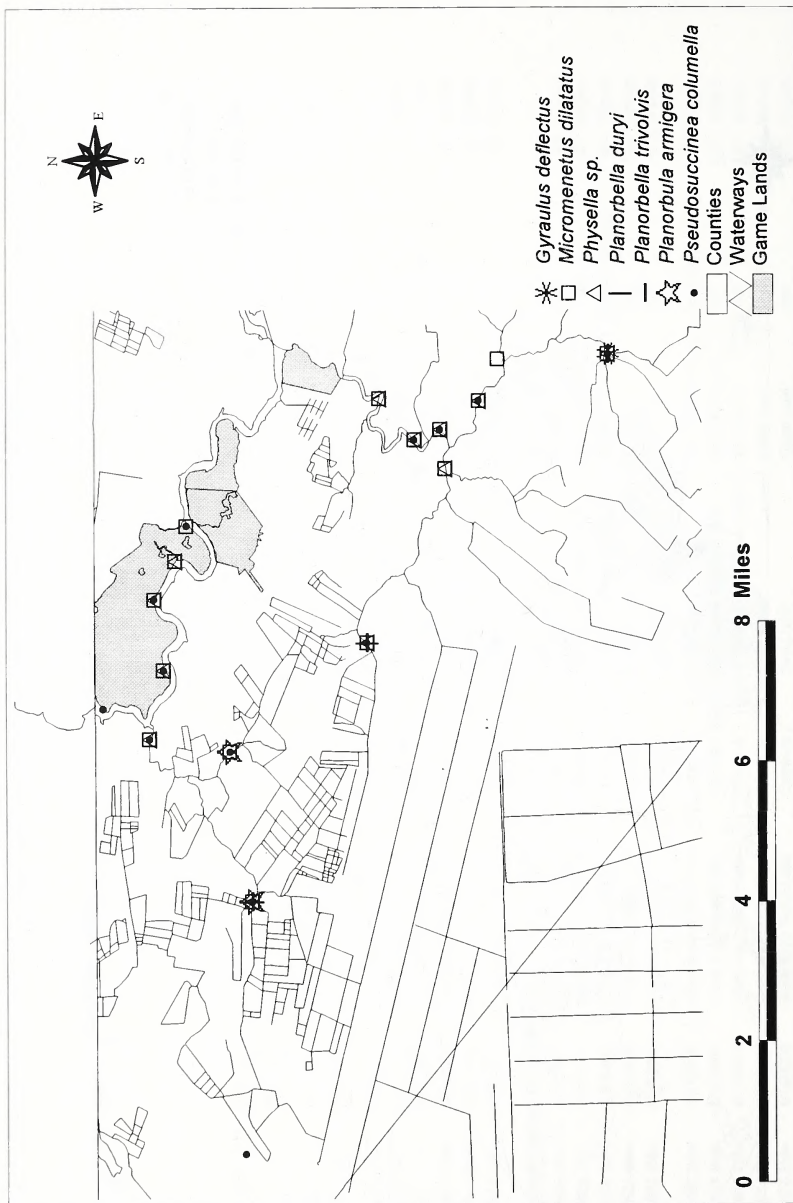


Figure 3e. Map of sites indicating where each species of pulmonate snail was collected in the Northwest River Marsh Game Land aquatic inventory, Currituck County, North Carolina, 2000.

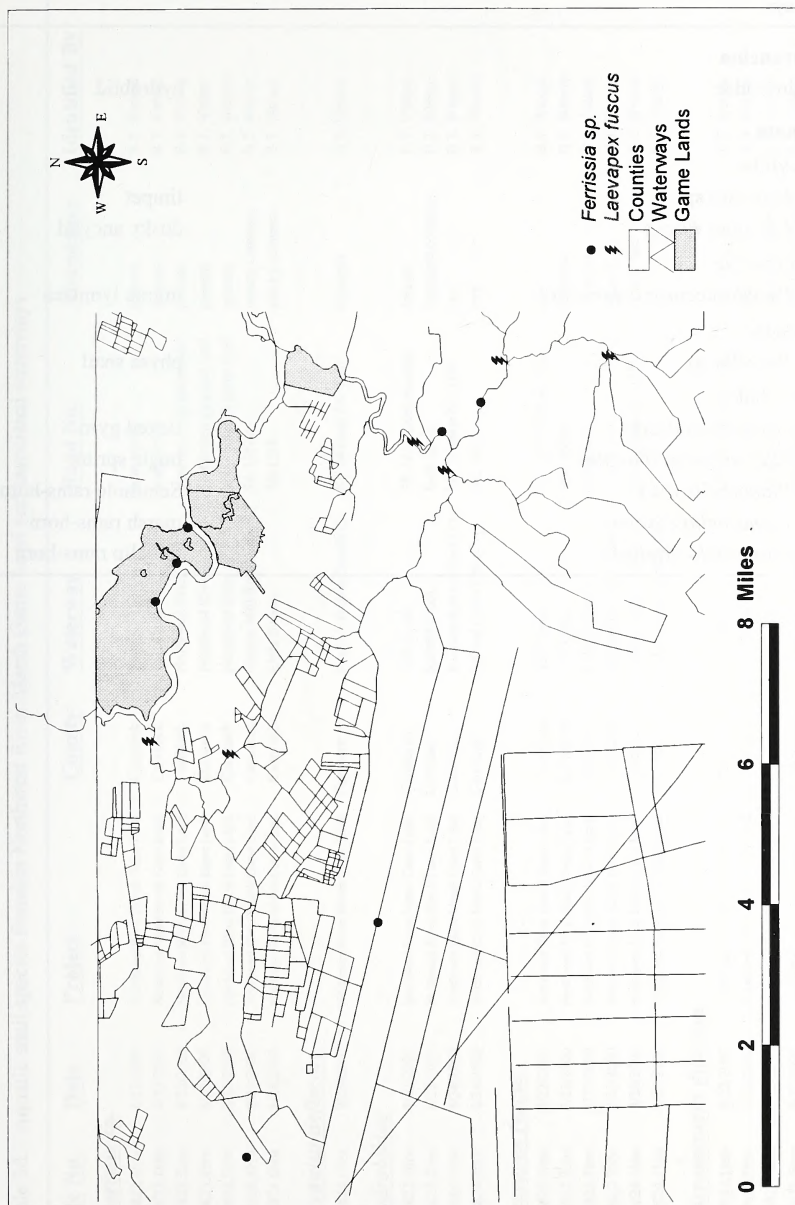


Figure 3f. Map of sites indicating where each species of ancylid was collected in the Northwest River Marsh Game Land aquatic inventory, Currituck County, North Carolina, 2000.

Table 3c. Aquatic snail species found in Northwest River Marsh Game Land and associated waterways.

Prosobranchia	
Hydrobiidae	hydrobiid
Pulmonata	
Ancylidae	
<i>Ferrissia</i> sp.	limpet
<i>Laevapex fuscus</i>	dusky ancylid
Lymnaeidae	
<i>Pseudosuccinea columella</i>	mimic lymnaea
Physidae	
<i>Physella</i> sp.	physa snail
Planorbidae	
<i>Gyraulus deflectus</i>	flexed gyro
<i>Micromenetus dilatatus</i>	bugle sprite
<i>Planorbella duryi</i>	Seminole rams-horn
<i>Planorbella trivolvis</i>	marsh rams-horn
<i>Planorbula armigera</i>	thicklip rams-horn

Table 3d. Aquatic snail species found in Northwest River Marsh Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
<i>Ferrissia</i> sp.							
000822.4btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Canal to Tull Creek	boat access	present	B.T. Watson
000823.1btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000823.3btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.4btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.5btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000824.4btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Guinea Mill Run Canal	SR 1387 +	patchy common	B.T. Watson
000824.6btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Light Swamp	SR 1218	patchy common	B.T. Watson
<i>Gyraulus deflexus</i>							
000824.1btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	common	B.T. Watson
<i>Hydrobiidae</i>							
000822.1btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	SR 1232 (boat access)	present	B.T. Watson
000823.2btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	localized common	B.T. Watson
000824.1btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	rare	B.T. Watson
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	rare	B.T. Watson
<i>Laevapex fuscus</i>							
000822.1btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	SR 1232 (boat access)	rare	B.T. Watson
000822.3btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	common	B.T. Watson
000823.2btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	common	B.T. Watson
000823.7btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson
000824.1btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	patchy rare	B.T. Watson
000824.3btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1222 -	rare	B.T. Watson
<i>Micromenetus dilatatus</i>							
000822.1btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	SR 1232 (boat access)	rare	B.T. Watson
000822.2btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	common	B.T. Watson
000822.3btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	patchy common	B.T. Watson
000822.4btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Canal to Tull Creek	boat access	patchy uncommon	B.T. Watson
000823.1btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	uncommon	B.T. Watson

Table 3d (cont.). Aquatic snail species found in Northwest River Marsh Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
<i>Micromenetus dilatatus</i>							
000823.2bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	present	B.T. Watson, A.E. Bogan
000823.3bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000823.4bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000823.5bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000823.6bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000823.7bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson
000824.1bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	rare	B.T. Watson
000824.2bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	rare	B.T. Watson
000824.3bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1222 -	rare	B.T. Watson
000824.5bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	rare	B.T. Watson
<i>Physella sp.</i>							
000822.2bvw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	rare	B.T. Watson
000822.3bvw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	patchy uncommon	B.T. Watson
000822.4bvw	8/22/2000	Northwest River Marsh Game Land	Currituck	Canal to Tull Creek	boat access	rare	B.T. Watson
000823.1bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000823.2bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	present	B.T. Watson
000823.4bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.5bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.6bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.7bvw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson
000824.1bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	patchy common	B.T. Watson
000824.2bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	rare	B.T. Watson
000824.5bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	common	B.T. Watson
<i>Planorbella duryi</i>							
000824.2bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	rare	B.T. Watson
000824.5bvw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	uncommon	B.T. Watson

Table 3d (cont.). Aquatic snail species found in Northwest River Marsh Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<u>Planorbella trivolvis</u>							
000824.1bw	8/24/2000	Northwest River Marsh Game	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	present	B.T. Watson
000824.2bw	8/24/2000	Northwest River Marsh Game	Currituck	Roland Creek Canal	NC 168 +	uncommon	B.T. Watson
000824.5bw	8/24/2000	Northwest River Marsh Game	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	rare	B.T. Watson
<u>Planorbula armigera</u>							
000824.3bw	8/24/2000	Northwest River Marsh Game	Currituck	Trib to Shingle Landing Ck	SR 1222 -	rare	B.T. Watson
000824.5bw	8/24/2000	Northwest River Marsh Game	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	common	B.T. Watson
<u>Pseudosuccinea columella</u>							
000822.3bw	8/22/2000	Northwest River Marsh Game	Currituck	Tull Creek	boat access	rare	B.T. Watson
000822.4bw	8/22/2000	Northwest River Marsh Game	Currituck	Canal to Tull Creek	boat access	common	B.T. Watson
000823.1bw	8/23/2000	Northwest River Marsh Game	Currituck	Tull Creek	boat access	uncommon	B.T. Watson
000823.3bw	8/23/2000	Northwest River Marsh Game	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000823.5bw	8/23/2000	Northwest River Marsh Game	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000823.6bw	8/23/2000	Northwest River Marsh Game	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000823.7bw	8/23/2000	Northwest River Marsh Game	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson
000823.8bw	8/23/2000	Northwest River Marsh Game	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000824.1bw	8/24/2000	Northwest River Marsh Game	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	rare	B.T. Watson
000824.2bw	8/24/2000	Northwest River Marsh Game	Currituck	Roland Creek Canal	NC 168 +	rare	B.T. Watson
000824.3bw	8/24/2000	Northwest River Marsh Game	Currituck	Trib to Shingle Landing Ck	SR 1222 -	rare	B.T. Watson
000824.5bw	8/24/2000	Northwest River Marsh Game	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	rare	B.T. Watson
000824.6bw	8/24/2000	Northwest River Marsh Game	Currituck	Light Swamp	SR 1218	rare	B.T. Watson

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debris, overhanging roots, cobble or large boulders, burrows or depressions, and in human debris (e.g., cans, tires) (Lodge and Hill 1994).

Crayfish are affected by both water and habitat quality. Changes in water quality that interfere with respiration (e.g., drastic temperature changes, acidification, pollution) can be detrimental to crayfish populations. Many crayfish are oxygen regulators and can survive changes in oxygen levels (Reiber 1995), but some are oxygen conformers and are less likely to successfully contend with these changes (Hobbs III 1991). Water pollution, caused by sources such as sewage, agricultural and urban runoff, acidification, and auto exhaust, can result in bioaccumulation of pesticides and trace heavy metals (e.g., lead, copper, cadmium). This can harm animals that consume crayfish in addition to directly causing negative effects on crayfish (e.g., mutation, reproductive failure, death) (Taylor et al. 1995, Daveikis and Alikhan 1996, Anderson et al. 1997, Zaranko et al. 1997). Habitat destruction can also negatively affect crayfish populations. Land use practices (e.g., agriculture, logging, development) can alter habitat resulting in fewer areas available as shelter to crayfish (Smith et al. 1996, Richter et al. 1997). For example, siltation and runoff can decrease macrophyte (a source of food and shelter) availability, and channelization can alter stream bed sculpture.

Ecological Interactions

Crayfish are both directly and indirectly linked to the ecosystems in which they live. Because they are omnivorous (i.e., consume both plant and animal food, living or dead), and because they are consumed by animals from various trophic levels, crayfish form multiple links in aquatic and terrestrial food webs (Lodge et al. 1994, Charlebois and Lamberti 1996, Nystrom et al. 1996). Thus, crayfish are involved in the transfer of large amounts of energy in these systems. Crayfish process nutrients and make them available to other animals by (1) breaking down large material via shredding into smaller sizes, and (2) converting nutrients into biomass. Crayfish feed on aquatic vegetation (e.g., macrophytes, algae, periphyton), macroinvertebrates (e.g., aquatic insects, mollusks, small crustaceans), and small vertebrates (e.g., amphibians, small/juvenile fish). Crayfish also consume nonliving organic matter such as leaf litter or terrestrial animal carcasses from the riparian zone or shore and decaying aquatic plant and animal matter (Lodge and Hill 1994). Crayfish in turn are consumed by invertebrates (including other crayfish), fish, amphibians, reptiles, birds, and mammals (Lodge and Hill 1994). Crayfish perform an important role as a member of symbiosis with many invertebrates and as host to various aquatic parasites (Lodge and Hill 1994). Crayfish also experience competition, both between species and among different sizes of individuals within a population (Lodge and Hill 1994).

The introduction of non-indigenous crayfishes to areas currently occupied by native crayfishes can result in competition or even extirpation of natives and can have impacts on other components of the ecosystem (Charlebois and Lamberti 1996, Perry 1998). For example, if crayfish become too abundant, they can be destructive to aquatic ecosystems by destroying more macrophytes than they consume, resulting in less habitat and food for other animals (Lodge et al. 1994, Nystrom et al. 1996). In fact, Lodge et al. (2000) consider nonindigenous crayfish introductions to be the single greatest threat to native crayfish biodiversity worldwide.

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Taxonomy, Distribution, and Statuses

In the United States and Canada, approximately 350 taxa of crayfish are recognized (Taylor et al. 1996, J.E. Cooper, NC State Museum of Natural Sciences, Curator of Crustaceans, pers. comm.). However, many species still await description (J.E. Cooper, NCSM, pers. comm.). For example, several current species are now recognized to be species complexes consisting of more than a single taxon. Conversely, animals grouped into several species or subspecies by different authors may actually belong to the same species. The greatest diversity of crayfishes occurs in the Southeast (Hobbs III 1991, Taylor et al. 1996), and North Carolina harbors at least 33 native (possibly up to 46) and 3 introduced species of *Cambarus*, *Procambarus*, *Orconectes*, and *Fallicambarus* (Cooper and Braswell 1995, J.E. Cooper, NCSM, pers. comm.). About half of the described crayfishes in North Carolina are of undetermined conservation status due to a lack of data on the distribution and abundance of these animals. Additionally, there are perhaps as many as a dozen native species yet to be described (J.E. Cooper, NCSM, pers. comm.). Of those species for which we have at least some information, the North Carolina Natural Heritage Program lists 10 species as significantly rare (LeGrand and Hall 1998), and the Scientific Council on Freshwater and Terrestrial Crustaceans proposes that 8 of North Carolina's species be of special concern, and that 13 species be put on a watch list (Clamp 1999). New information about current distributions has recently been reported (Cooper and Braswell 1995, Cooper et al. 1998). However, given that undescribed species exist and that we have much to learn about the distributions of crayfishes in North Carolina, it is imperative that we continue to improve our knowledge of crayfish by contributing to the growing database.

Methods

The crayfish surveys of North River and Northwest River Marsh game lands were conducted during the summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were accessed at bridge crossings or roadside access points, or in rivers via motorboat. Because the waterways were mostly swampy, and therefore difficult to traverse, we surveyed as many habitat types as possible near the access points.

Crayfishes were collected using a number of different techniques, depending on the conditions of the waterway being sampled (e.g., substrate type, depth of water). We collected crayfishes by hand or with dip nets from the substrate in which they were hiding (e.g., detritus, leaf packs, root wads, or under rocks). We trapped (minnow traps, set overnight) in North River Game Land. We also collected crayfishes in both game lands by electrofishing at sites where conductivity was not too high to preclude using this method (only one site possible in Northwest River Marsh Game Land). Trapping and electrofishing generally proved to be a less successful method than visual location and dip netting. We dug burrows in Northwest River Marsh Game Land. Digging yielded crayfish about half the time or less. Collected specimens were preserved and stored in 70% ethanol.

Successful identification of many cambarid crayfishes usually requires collection of reproductive (form I) males. Certain features of their gonopods – the first pair of abdominal appendages, or pleopods – can be important in their taxonomy. Form I males can be distinguished from form II males by the advanced development of the terminal elements at the tips of their gonopods. In addition, form I males have highly developed hooks on the ischia of certain walking legs

(pereiopods) that are used to hold the female during copulation. The size and shape of their chelae may also vary at this stage. Some common characteristics used in identification of non-form I males are carapace length and depth/width ratio, areola width and length, presence and placement of spines, rostrum shape, color, and chela characteristics. Crayfishes were identified by using a taxonomic key (Hobbs Jr. 1991) and a checklist (Hobbs Jr. 1989), by comparing individuals to reference collection specimens (North Carolina Wildlife Resources Commission, and North Carolina State Museum of Natural Sciences), and via personal communication with Dr. J.E. Cooper. Common names are according to Clamp (1999). As our understanding of crayfish taxonomy continues to improve, the identifications of the species we collected may change.

In addition to identifying individuals, we noted approximate abundances of each type of crayfish collected, and quantified average carapace lengths of those collected (from the tip of the rostrum to the posterior carapace edge). We also looked for evidence of recent reproduction and estimated habitat preferences of each species based on the areas from which they were collected. We recorded presence/absence data for each species encountered at each site visited to allow a crude estimate of the distribution of each species within the waterways associated with the game lands. These data will also be added to a larger database describing statewide distributions. Where possible, we recorded notes on ecological interactions (e.g., abundance of food, presence of competitors or predators, quality of habitat). For logistical and ethical reasons, we did not preserve every crayfish collected.

For crustaceans (crayfishes, crabs, and shrimps), a survey effectiveness score (SES) was determined at each site and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

North River Game Land

Over 5 days from 26 June to 16 August 2000, 23 sites were inventoried. Crayfish were collected or observed at 12 sites (Figure 4a and Table 4a). Crayfish were observed at 9 sites, and burrows only were observed at 2 sites. Four species of crayfish were collected during the survey period: *Cambarus* (*Lacunicambarus*) *diogenes* Girard, 1852, *Fallicambarus* (*Creaserinus*) *fodiens* (Cottle, 1863), *Procambarus* (*Ortmannicus*) *acutus* (Girard, 1852), and *Procambarus* (*Scapulicambarus*) *clarkii* (Girard, 1852), a nonindigenous species. *Palaemonetes paludosus* (freshwater shrimp), *Callinectes sapidus* (blue crab), and *Rhithropanopeus harrisi* (white-fingered mud crab) were also collected during this survey.

Cambarus (*L.*) *diogenes* (devil crayfish) was found at 4 sites. At these sites, several juveniles only were collected from detritus along edges. Because this species is a primary burrower, it is likely that it is more common than our survey indicates. We noted the presence of burrows at 1 site where *F. fodiens* was found, at 2 sites where *C. diogenes* occurred, and at 2 sites where no crayfish were collected. The carapace coloration was mostly slate blue-brown in color, legs and undersides were pale blue, and all sutures and chelae edges were bright red. This species is

considered stable and is found throughout much of the eastern Piedmont and Coastal Plain of this and other states.

Fallicambarus (C.) fodiens (no common name available) was found at only 3 sites, and we only collected a few animals or carapaces at each. However, this species is a primary burrower, so it is likely that it is more common than our survey indicated. We noted the presence of burrows at 1 site where *F. fodiens* was found, at 2 sites where *C. diogenes* occurred, and at 2 sites where no crayfish were collected. The presence of juveniles indicated that reproduction had recently occurred. These animals were brown in color, with speckling on the carapace. This species is considered stable and is found throughout much of the eastern Piedmont and Coastal Plain of this and other states.

Procambarus (O.) acutus (White River crayfish) was collected at less than half (9) of the surveyed sites, and abundance ranged from rare to uncommon. Reproduction was currently ongoing, as juveniles were collected from 5 sites. Animals were collected from various types of habitat, but most often from detritus or vegetation in areas with slow flow. This species is one of the largest *Procambarus* species occurring in North Carolina. Its coloration varies across its range. Generally, carapace color consists of different shades of tan, brown, and rust, but can also be olive green. Adornment includes dark speckling, cream mottling, and blurred stripes along carapace sides, and a wide dark stripe on the dorsal abdomen. This species is considered stable and is found throughout much of the Piedmont and Coastal Plain of this and other states.

Procambarus (S.) clarkii (red swamp crayfish) was present at 1 site, and no other species of crayfish was found there. One form II male was collected in a trap, and one female was collected via dip net (but later escaped). This species is one of the largest *Procambarus* species occurring in North Carolina, and is similar in size to *P. acutus*. Generally, carapace color consists of different shades of tan, brown, and red-brown, with speckling or mottling. Often, the carapace and chelae appear bumpy, and chelae of adults usually bear bright red bumps and edges. This species can be differentiated from *P. acutus* by its linear areola. This species is nonindigenous, and wild populations have been documented in many parts of the state.

Palaemonetes paludosus (freshwater shrimp) was collected from 4 sites. Animals were usually found in vegetation along banks. *Callinectes sapidus* (blue crab) was collected from 1 site, and *Rhithropanopeus harrisi* (white-fingered mud crab) was collected at 2 sites during this survey, presumably where salinities were higher than in freshwater.

Northwest River Marsh Game Land

Over 3 days from 22 to 24 August 2000, 18 sites were inventoried. Crayfish were collected or observed at 8 sites (Figure 4b and Table 4b). Crayfish were not observed at 8 sites, and burrows were not observed at 2 sites. Only 1 species of crayfish was collected during the survey period: *Procambarus (Ormannicus) acutus* (Girard, 1852). *Palaemonetes paludosus* (freshwater shrimp), *Callinectes sapidus* (blue crab), and *Rhithropanopeus harrisi* (white-fingered mud crab) were also collected during this survey.

Procambarus (O.) acutus (White River crayfish) occurred at less than half (8) of the sites surveyed and was the only crayfish species collected during this survey. Across most sites, the abundance of this species ranged from rare to common. Reproduction was currently ongoing, as

juveniles were collected from most sites. Animals were collected from various types of habitat, but most often from detritus or vegetation in areas with slow flow. This species is one of the largest *Procambarus* species occurring in North Carolina. Its coloration varies across its range. Generally, carapace color consists of different shades of tan, brown, and rust, but can also be olive green. Adornment includes dark speckling, cream mottling, and blurred stripes along carapace sides, and a wide dark stripe on the dorsal abdomen. This species is considered stable and is found throughout much of the Piedmont and Coastal Plain of this and other states. Sizes were calculated for 1 sample only; we did not record measurements for every individual collected. Female carapace length ranged from 21 to 33 mm; male carapace length ranged from 17 to 32 mm; and unsexed juvenile carapace length ranged from 5.5 to 10 mm.

At 2 sites, burrows were present. At 1 site, burrows had chimneys but were old and dried. At the other site, burrows were chimneyless and occurred as holes in hard clay amongst roots in the floodplain. Digging yielded no crayfish at either site. These burrows may indicate the presence of either *Cambarus (L.) diogenes* or *Fallicambarus (C.) fodiens*.

Palaemonetes paludosus (freshwater shrimp) was collected from 10 sites. Animals were usually found in vegetation along banks. *Callinectes sapidus* (blue crab) was collected from muddy substrate at 6 sites, and *Rhithropanopeus harrisii* (white-fingered mud crab) was collected at 2 sites during this survey, presumably where salinities were higher than in freshwater.

Discussion

The overall diversity of crayfishes in this system was low, likely because a large portion of the survey area contained brackish water. *Procambarus acutus* was the most widespread species we encountered but occurred at less than half of the sites surveyed and was generally uncommon. *Cambarus diogenes* and *F. fodiens* were found at only 4 and 3 sites in North River Game Land, respectively, and were rare at these localities. These species were not collected from Northwest River Marsh Game Land, although the presence of burrows indicates that they likely occur there as well. *Procambarus clarkii* was collected from only one site in the North River Game Land and was rare there. All 3 native species occurred with each of the other species at various waterways in the North River Game Land. The overall SES for North River and Northwest River Marsh game lands were 2.63 and 1.42, respectively, indicating that our survey effectiveness may have limited the resulting species composition.

Aspects of crayfish communities can tell us something about the system in which they occur. Although we did not directly test water quality, it was clear that the conditions in North River and Northwest River Marsh game lands limited survival of crayfishes because of salinities higher than those found in freshwater. Current reproduction was evident for all native species. Because we collected only adult *P. clarkii*, we cannot say whether this species was reproducing. Potential food sources (e.g., allochthonous and autochthonous organic debris) were abundant, and vegetation was present. Crayfishes were rarely seen away from cover. Predation pressure on these crayfishes (especially juveniles) was likely low because the fish community in this system was poor (see *Fish* section of this report). However, plenty of cover-providing habitat was available to crayfishes and likely lessened direct impact by predation. It is unclear whether any of the less widespread species was limited by competition or by abiotic factors other than salinity, such as low dissolved oxygen or high acidity.

During our survey, we found all 3 of the species historically known to occur in the Pasquotank River Basin. In addition, we found 1 nonindigenous species not previously known to occur there. Although it is believed that *Cambarus (P.)* sp. C (a species complex related to *C. (P.) acuminatus* Faxon, 1884) may occur in this river basin, we did not find any specimens of this species. This survey has helped to further clarify distribution boundaries of several species in the Pasquotank River Basin and has alerted us to the presence of a nonindigenous species.

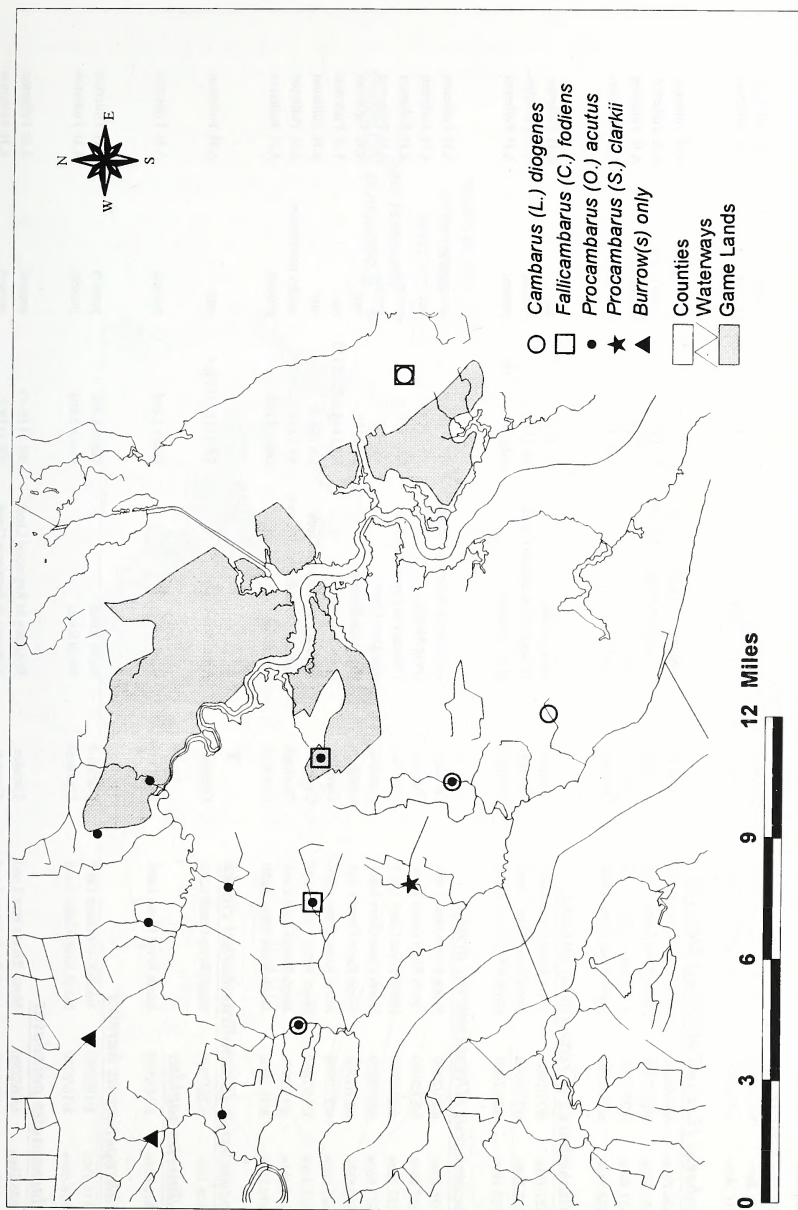


Figure 4a. Map of sites indicating where each species of crayfish was collected in the North River Game Land aquatic inventory, Camden and Currituck counties, North Carolina, 2000.

Table 4a. Crustaceans found in North River Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
<u>Burrow(s) only</u>							
000815.2bw	8/15/2000	North River Game Land	Camden	Sawyer Creek	SR 1203 +	present	A.H. Fullerton
000815.3bw	8/15/2000	North River Game Land	Camden	Run Swamp Canal	NC 34 -	present	A.H. Fullerton
<u>Cambarus (Lacunicambarus) diogenes</u>							
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	patchy rare	A.H. Fullerton
000626.3bw	6/26/2000	North River Game Land	Camden	Tributary to Pasquotank River	SR 1100	patchy rare	A.H. Fullerton
000627.4bw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	present	A.H. Fullerton
000628.1bw	6/28/2000	North River Game Land	Currituck	Maple Swamp	Bike 3	present	A.H. Fullerton
<u>Fallicambarus (Creaserinus) fodiens</u>							
000627.1bw	6/27/2000	North River Game Land	Camden	Great Swamp	SR 1115 -	rare	A.H. Fullerton
000627.2bw	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	present	A.H. Fullerton
000628.1bw	6/28/2000	North River Game Land	Currituck	Maple Swamp	Bike 3	present	A.H. Fullerton
<u>Procambarus (Ortmannicus) acutus</u>							
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	uncommon	A.H. Fullerton
000627.1bw	6/27/2000	North River Game Land	Camden	Great Swamp	SR 1115 -	rare	A.H. Fullerton
000627.2bw	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	present	A.H. Fullerton
000627.4bw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	present	A.H. Fullerton
000627.5bw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp	SR 1135 -	rare	A.H. Fullerton
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	rare	A.H. Fullerton
000815.1bw	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	rare	A.H. Fullerton
000815.4bw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	patchy uncommon	A.H. Fullerton
000816.3bw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	present	A.H. Fullerton
<u>Procambarus (Scapulicambarus) clarkii</u>							
000626.1bw	6/26/2000	North River Game Land	Camden	Portohonk Creek	SR 1111 (1110) +	rare	A.H. Fullerton
<u>Callinectes sapidus</u>							
000816.6bw	8/16/2000	North River Game Land	Currituck	North River	Game Land	present	A.H. Fullerton
<u>Rhithropanopeus harrisi</u>							
000816.4bw	8/16/2000	North River Game Land	Currituck	North River	Game Land	present	A.H. Fullerton
000816.6bw	8/16/2000	North River Game Land	Currituck	North River	Game Land	present	A.H. Fullerton
<u>Palaemonetes paldosus</u>							
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	present	A.H. Fullerton
000627.2bw	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	present	A.H. Fullerton
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	present	A.H. Fullerton
000815.4bw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	common	A.H. Fullerton

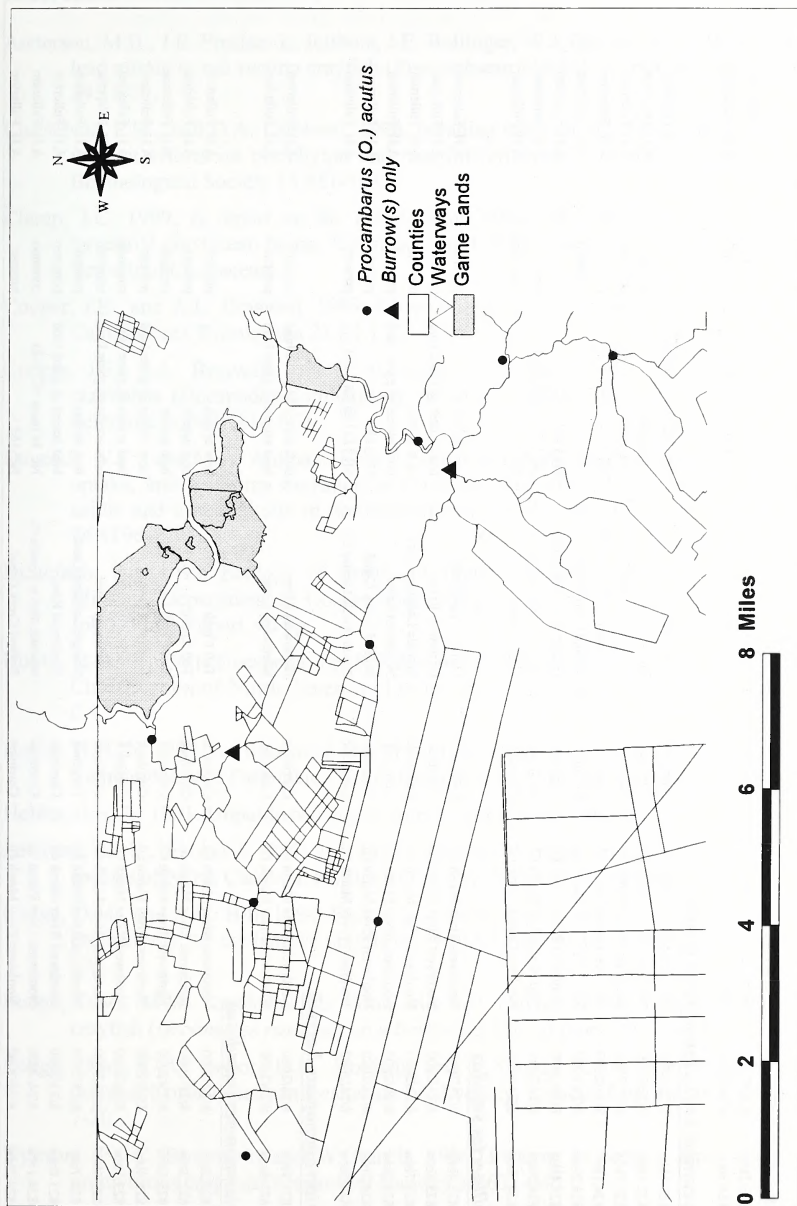


Figure 4b. Map of sites indicating where each species of crayfish was collected in the Northwest River Marsh Game Land aquatic inventory, Currituck County, North Carolina, 2000.

Table 4b. Crustaceans found in Northwest River Marsh Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
<u>Burrow(s) only</u>							
000823.2bw	8/23/2000	Northwest River Marsh GL	Currituck	Roland Creek	boat access	present	A.H. Fullerton
000824.3bw	8/24/2000	Northwest River Marsh GL	Currituck	Trib to Shingle Landing Ck	SR 1222 -	present	A.H. Fullerton
<u>Procambarus (Ortmannicus) acutus</u>							
000822.1bw	8/22/2000	Northwest River Marsh GL	Currituck	Tull Creek	SR 1232 (boat access)	rare	A.H. Fullerton
000822.3bw	8/22/2000	Northwest River Marsh GL	Currituck	Tull Creek	boat access	present	A.H. Fullerton
000823.7bw	8/23/2000	Northwest River Marsh GL	Currituck	Shingle Landing Creek	boat access	present	A.H. Fullerton
000824.1bw	8/24/2000	Northwest River Marsh GL	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	rare	A.H. Fullerton
000824.2bw	8/24/2000	Northwest River Marsh GL	Currituck	Roland Creek Canal	NC 168 +	common	A.H. Fullerton
000824.4bw	8/24/2000	Northwest River Marsh GL	Currituck	Guiana Mill Run Canal	SR 1387 +	rare	A.H. Fullerton
000824.5bw	8/24/2000	Northwest River Marsh GL	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	rare	A.H. Fullerton
000824.6bw	8/24/2000	Northwest River Marsh GL	Currituck	Light Swamp	SR 1218	common	A.H. Fullerton
<u>Callinectes sapidus</u>							
000822.4bw	8/22/2000	Northwest River Marsh GL	Currituck	Canal to Tull Creek	boat access	common	A.H. Fullerton
000823.4bw	8/23/2000	Northwest River Marsh GL	Currituck	Northwest River	boat access @ game land	present	A.H. Fullerton
000823.7bw	8/23/2000	Northwest River Marsh GL	Currituck	Shingle Landing Creek	boat access	present	A.H. Fullerton
000823.8bw	8/23/2000	Northwest River Marsh GL	Currituck	Northwest River	boat access @ game land	present	A.H. Fullerton
000824.2bw	8/24/2000	Northwest River Marsh GL	Currituck	Roland Creek Canal	NC 168 +	present	A.H. Fullerton
000824.3bw	8/24/2000	Northwest River Marsh GL	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	present	A.H. Fullerton
<u>Rithropanopeus harrisi</u>							
000823.3bw	8/23/2000	Northwest River Marsh GL	Currituck	Northwest River	boat access @ game land	present	A.H. Fullerton
000823.6bw	8/23/2000	Northwest River Marsh GL	Currituck	Northwest River	boat access @ game land	present	A.H. Fullerton
<u>Palaemonetes paludosus</u>							
000822.2bw	8/22/2000	Northwest River Marsh GL	Currituck	Tull Creek	boat access	present	A.H. Fullerton
000822.3bw	8/22/2000	Northwest River Marsh GL	Currituck	Tull Creek	boat access	present	A.H. Fullerton
000823.1bw	8/23/2000	Northwest River Marsh GL	Currituck	Tull Creek	boat access	present	A.H. Fullerton
000823.4bw	8/23/2000	Northwest River Marsh GL	Currituck	Northwest River	boat access @ game land	present	A.H. Fullerton
000823.5bw	8/23/2000	Northwest River Marsh GL	Currituck	Northwest River	boat access @ game land	common	A.H. Fullerton
000823.6bw	8/23/2000	Northwest River Marsh GL	Currituck	Northwest River	boat access @ game land	common	A.H. Fullerton
000823.7bw	8/23/2000	Northwest River Marsh GL	Currituck	Shingle Landing Creek	boat access	present	A.H. Fullerton
000823.8bw	8/23/2000	Northwest River Marsh GL	Currituck	Northwest River	boat access @ game land	common	A.H. Fullerton
000824.1bw	8/24/2000	Northwest River Marsh GL	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	common	A.H. Fullerton
000824.2bw	8/24/2000	Northwest River Marsh GL	Currituck	Roland Creek Canal	NC 168 +	present	A.H. Fullerton

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FRESHWATER FISHES

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Introduction

Fishes are the most numerous and diverse of the major vertebrate groups. Their various morphological, behavioral, reproductive, and physiological adaptations have allowed them to dominate the waters of the world. Fishes can be found in a broad array of habitats, including vernal pools, mountain streams, and the ocean floor. Their dominance is reflected in the number of living species. Over 24,600 species have been described (Moyle and Cech 1996), and it is believed that this number may increase to approximately 28,500 (Nelson 1994). The North American continent harbors approximately 1,100 species of freshwater fish (Burr and Mayden 1992), with 790 (75%) species occurring in the United States (Page and Burr 1991). Nearly 200 native species can be found in North Carolina (Menhinick 1991).

While most of the attention from the public and fisheries biologists is directed towards the game fishes, these species make up only about 5% of the freshwater fish fauna in the United States. The remaining 95% are little known, but charismatic, nongame species, such as darters and minnows. Nongame fishes play a vital role in the balance of aquatic ecosystems. Their diets are diverse, and, in turn, they serve as dietary components for sport fishes, water birds, and other wildlife. They also are important indicators of water quality and can signal when aquatic ecosystems are being negatively impacted. Game fishes also are important components of aquatic ecosystems and provide a source of recreation and employment for many people. Unfortunately, in 1989, the American Fisheries Society regarded 364 North American freshwater fish species as endangered, threatened, or special concern, an increase of 45% in just 10 years (Williams et al. 1989). This number represents approximately one-third of the North American native freshwater fish fauna. Likewise, the southern United States, which supports more native fishes than any comparable size on the North American continent north of Mexico, has experienced a 75% increase in jeopardized fishes since 1989 and a 125% increase in 20 years (Warren et al. 2000). In North Carolina, approximately 25% of the freshwater fishes are state listed. Some of the reasons for this decline include habitat alteration and loss, chemical pollution, overexploitation, and introduction of exotic species. Given this information, it is essential that we better understand the taxonomy, distribution, and conservation needs of the various taxa. Therefore, a freshwater fish inventory of the waterways in and around the state-owned North River Game Land and Northwest River Marsh Game Land was initiated to ascertain some of this needed information.

Methods

The freshwater fish surveys of North River Game Land and Northwest River Marsh Game Land were conducted during the summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were accessed at bridge crossings or roadside access points, and sites along the North and Northwest rivers were surveyed via motorboat. Because the waterways

were predominantly swamps or canals and therefore difficult to traverse, we surveyed as many habitat types as possible near the access points.

Freshwater fishes were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). The most common method used was dip netting. This method was predominantly used because most of the waterways we encountered had high conductivities making them difficult to electrofish. We typically use electrofishing as our primary survey technique due to its advantages regarding efficiency and effectiveness, but only 7 sites between the 2 game lands were sampled in this manner. Given the conditions of the waterways we encountered, the use of minnow traps also was implemented to help augment the accuracy of our surveys. Most fishes collected were identified to species and released unharmed. However, it was necessary to perform some of the identifications in the laboratory. These identifications were carried out by fixing the fish in 10% formalin and preserving them in 70% ethanol. Once the fishes were preserved, they were identified with the use of a compound microscope (Nikon). Fishes were identified according to Menhinick (1991), Page and Burr (1991), Rhode et al. (1994), and Jenkins and Burkhead (1994). Dr. Wayne C. Starnes and others (G.M. Hogue, T.L. Fullbright, and Dr. M.E. Raley) from the NC State Museum of Natural Sciences verified some of the identifications. Besides presence-absence data, relative abundance and recent reproduction information were noted for each species to determine population health.

For fishes, a survey effectiveness score (SES) was determined at each site and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

North River Game Land

Over 5 days from 26 June to 16 August 2000, 23 sites were surveyed, and fish were collected or observed at 20 sites (Figure 5a). Fourteen species representing 9 families were documented during the survey of North River Game Land (Tables 5a and 5b). Of the 46 species of freshwater fish species that have been documented in the Camden and Currituck counties portion of the Pasquotank River Basin (Menhinick 1991), we confirmed the presence of only 14 of these species. Limitations as to our sampling techniques, and access of all available habitats and sampling range within the counties were the most likely reasons for the absence of particular species. Overall, abundance, distribution, and recent reproduction were difficult to determine for most fish species given that our SES was 2.04.

Northwest River Marsh Game Land

Over 3 days from 22 to 24 August, 18 sites were surveyed, and fishes were collected or observed at 17 of those localities (Figure 5b). Fifteen species representing 9 families were documented during the survey of Northwest River Marsh Game Land (Tables 5c and 5d). Of the approximately 39 species that have been documented in the Currituck County portion of the Pasquotank River Basin (Menhinick 1991), we confirmed the presence of only 14 of these species. Limitations as to our sampling techniques, and access of all available habitats and

sampling range within the county were the most likely reasons for the absence of particular species. We did document the presence of 1 species that was not previously documented from the Currituck County portion of the Pasquotank River Basin: *Gambusia holbrooki* (eastern mosquitofish). Overall, abundance, distribution, and recent reproduction were difficult to determine for most fish species given that our SES was 1.22.

Discussion

The waterways associated with North River Game Land and Northwest River Marsh Game Land contain a relatively low diversity and distribution of fish species given past records and distributions (Menhinick 1991). Overall, 19 species representing 11 families were collected between the 2 game lands. With the exception of *Gambusia holbrooki*, most of the species tended to occur over a relatively restricted area. Species abundance was typically low at many sites with no single family comprising a majority of the biomass. The low distribution and abundance of a number of the species were likely significantly affected by the lack of intensive survey techniques. A number of sites had characteristics that made them virtually impossible to backpack electrofish, while even some of the sites we electrofished were difficult due to the water clarity. Therefore, dip netting became the primary, but less than desired, technique during the survey, resulting in an average SES below 2 for the game lands. Overall, the area we surveyed was mostly rural, resulting in minimal urbanization effects and some agricultural impacts, which may tend to reflect different results than those reported here. Unfortunately, we do not have any recent survey results for comparison to obtain an accurate reflection of the species composition and distribution of the area.

While no threatened or endangered fish species was collected during the survey of North River Game Land or Northwest River Marsh Game Land, continual research and status surveys are needed to determine the present status of each species. A single fish species (*Gambusia holbrooki*) was collected during the survey that was previously undocumented from the Currituck County portion of the Pasquotank River Basin (Menhinick 1991), which could be due to a lack of surveys in the area. However, since the eastern mosquitofish is a common fish, it is surprising that past surveys did not result in the collection of this species from the area. Current land management practices, including agriculture and urbanization, are having an effect on the fish fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

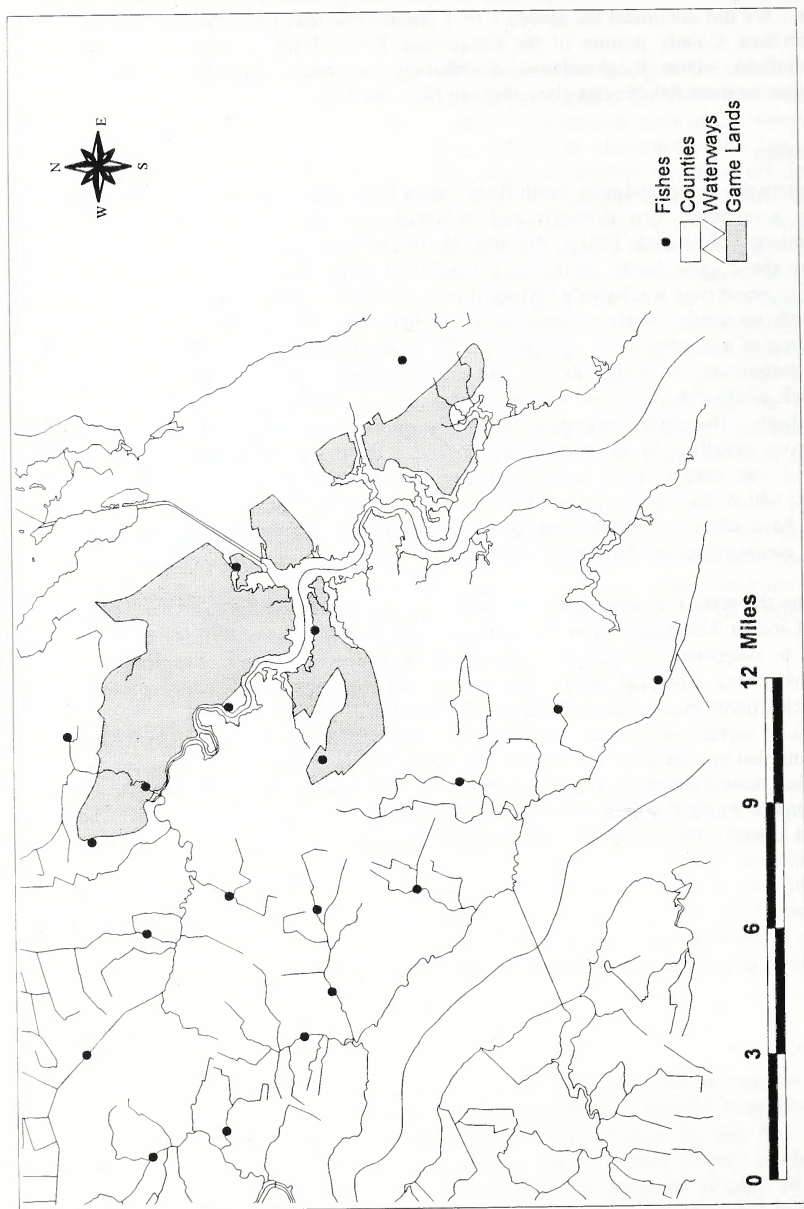


Figure 5a. Map of sites indicating where fishes were collected in the North River Game Land aquatic inventory, Camden and Currituck counties, North Carolina, 2000.

Table 5a. Freshwater fish species found in North River Game Land and associated waterways.

Amblyopsidae	
<i>Chologaster cornuta</i>	swampfish
Anguillidae	
<i>Anguilla rostrata</i>	american eel
Aphredoderidae	
<i>Aphredoderus sayanus</i>	pirate perch
Centrarchidae	
<i>Acantharchus pomotis</i>	mud sunfish
<i>Centrarchus macropterus</i>	flier
<i>Chaenobryttus gulosus</i>	warmouth
<i>Enneacanthus gloriosus</i>	bluespotted sunfish
<i>Lepomis gibbosus</i>	pumpkinseed
<i>Lepomis macrochirus</i>	bluegill
Cyprinidae	
<i>Notemigonus crysoleucas</i>	golden shiner
Esocidae	
<i>Esox americanus</i>	redfin pickerel
Ictaluridae	
<i>Ameiurus nebulosus</i>	brown bullhead
Poeciliidae	
<i>Gambusia holbrookii</i>	eastern mosquitofish
Umbridae	
<i>Umbra pygmaea</i>	eastern mudminnow

Table 5b. Freshwater fish species found in North River Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<u><i>Acantharchus pomotis</i></u>							
000628.1bw	6/28/2000	North River Game Land	Currituck	Maple Swamp	Bike 3	abundant	B. T. Watson
<u><i>Ameiurus nebulosus</i></u>							
000626.1bw	6/26/2000	North River Game Land	Camden	Swamp near Camden Point	SR 1162	present	B. T. Watson
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	rare	B. T. Watson
<u><i>Anguilla rostrata</i></u>							
000627.3bw	6/27/2000	North River Game Land	Camden	Areneuse Creek	NC 343	uncommon	B. T. Watson
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	rare	B. T. Watson
000816.3bw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	present	B. T. Watson
<u><i>Aphredoderus sayanus</i></u>							
000626.1bw	6/26/2000	North River Game Land	Camden	Portohonk Creek	SR 1111 (1110) +	present	B. T. Watson
000627.1bw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	common	B. T. Watson
000627.2bw	6/27/2000	North River Game Land	Camden	Tributary to Areneuse Creek	SR 1119 +	present	B. T. Watson
000627.3bw	6/27/2000	North River Game Land	Camden	Areneuse Creek	NC 343	common	B. T. Watson
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	rare	B. T. Watson
<u><i>Centrarchus macropterus</i></u>							
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	common	B. T. Watson
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	common	B. T. Watson
<u><i>Chaenobryttus gulosus</i></u>							
000627.6bw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	rare	B. T. Watson
<u><i>Chologaster cornuta</i></u>							
000627.1bw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	common	B. T. Watson

Table 5b (cont.). Freshwater fish species found in North River Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<i>Enneacanthus gloriosus</i>							
000626.2btw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	present	B.T. Watson
000627.1btw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	rare	B.T. Watson
000628.1btw	6/28/2000	North River Game Land	Currituck	Maple Swamp	Bike 3	rare	B.T. Watson
000816.3btw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	present	B.T. Watson
000816.5btw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	present	B.T. Watson
<i>Esox americanus</i>							
000626.1btw	6/26/2000	North River Game Land	Camden	Portohonk Creek	SR 1111 (1110) +	present	B.T. Watson
000627.1btw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	rare	B.T. Watson
000627.2btw	6/27/2000	North River Game Land	Camden	Tributary to Ateneuse Creek	SR 1119 +	present	B.T. Watson
000627.6btw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	abundant	B.T. Watson
000628.1btw	6/28/2000	North River Game Land	Currituck	Maple Swamp	Bike 3	uncommon	B.T. Watson
000815.1btw	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	present	B.T. Watson
<i>Esox sp.</i>							
000627.5btw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (Trib to Indiantown Creek)	SR 1135 -	rare	B.T. Watson
<i>Gambusia holbrooki</i>							
000626.1btw	6/26/2000	North River Game Land	Camden	Portohonk Creek	SR 1111 (1110) +	present	B.T. Watson
000626.2btw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	common	B.T. Watson
000626.3btw	6/26/2000	North River Game Land	Camden	Tributary to Pasquotank River	SR 1100	abundant	B.T. Watson
000626.4btw	6/26/2000	North River Game Land	Camden	Swamp near Camden Point	SR 1162	abundant	B.T. Watson
000627.1btw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	rare	B.T. Watson
000627.2btw	6/27/2000	North River Game Land	Camden	Tributary to Ateneuse Creek	SR 1119 +	common	B.T. Watson
000627.3btw	6/27/2000	North River Game Land	Camden	Ateneuse Creek	NC 343	present	B.T. Watson
000627.4btw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	common	B.T. Watson
000627.5btw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (Trib to Indiantown Creek)	SR 1135 -	uncommon	B.T. Watson

Table 5b (cont.). Freshwater fish species found in North River Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<u>Gambusia holbrooki</u>							
000627.6btw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	common	B.T. Watson
000815.1btw	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	common	B.T. Watson
000815.3btw	8/15/2000	North River Game Land	Camden/Currituck	Run Swamp Canal	NC 34 -	uncommon	B.T. Watson
000815.4btw	8/15/2000	North River Game Land	Currituck	Tributary to Indiantown Creek	SR 1148 +	present	B.T. Watson
000816.1btw	8/16/2000	North River Game Land	Currituck	Taylor Bay	Game Land	present	B.T. Watson
000816.3btw	8/16/2000	North River Game Land	Currituck	East Creek	Game Land	present	B.T. Watson
000816.5btw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	uncommon	B.T. Watson
000816.6btw	8/16/2000	North River Game Land	Currituck	North River	Game Land	uncommon	B.T. Watson
<u>Lepomis gibbosus</u>							
000627.4btw	6/27/2000	North River Game Land	Camden	Mill Dam Creek	NC 343	present	B.T. Watson
000627.6btw	6/27/2000	North River Game Land	Currituck	Great Swamp	SR 1148 & SR 1153	common	B.T. Watson
000628.1btw	6/28/2000	North River Game Land	Currituck	Maple Swamp	Bike 3	rare	B.T. Watson
<u>Lepomis macrochirus</u>							
000816.5btw	8/16/2000	North River Game Land	Currituck	Inlet to North River	Game Land	present	B.T. Watson
<u>Lepomis sp.</u>							
000626.2btw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 -/+	present	W.C. Starnes
<u>Notemigonus crysoleucas</u>							
000626.1btw	6/26/2000	North River Game Land	Camden	Porthook Creek	SR 1111 (1110) +	present	B.T. Watson, W.C. Starnes
000627.3btw	6/27/2000	North River Game Land	Camden	Areneuse Creek	NC 343	present	B.T. Watson

Table 5b (cont.). Freshwater fish species found in North River Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<i>Umbrapygmaea</i>							
000626.2bw	6/26/2000	North River Game Land	Camden	Tributary to Raymond Creek	SR 1110 +/-	present	B.T. Watson
000626.3bw	6/26/2000	North River Game Land	Camden	Tributary to Pasquotank River	SR 1100	present	B.T. Watson
000626.4bw	6/26/2000	North River Game Land	Camden	Swamp near Camden Point	SR 1162	common	B.T. Watson
000627.1bw	6/27/2000	North River Game Land	Camden	Great Island Swamp	SR 1115 -	uncommon	B.T. Watson
000627.5bw	6/27/2000	North River Game Land	Camden	Halfmoon Swamp (Trib to Indiantown Creek)	SR 1135 -	uncommon	B.T. Watson
000627.7bw	6/27/2000	North River Game Land	Currituck	Great Swamp	US 158 @ SR 1246	present	B.T. Watson
000628.1bw	6/28/2000	North River Game Land	Currituck	Maple Swamp	Bike 3	rare	B.T. Watson
000815.1bw	8/15/2000	North River Game Land	Camden	Tributary to Sawyers Creek	US 158 +	present	B.T. Watson
000815.2bw	8/15/2000	North River Game Land	Camden	Sawyer Creek	SR 1203 +	present	B.T. Watson
000815.3bw	8/15/2000	North River Game Land	Camden/Currituck	Run Swamp Canal	NC 34 -	common	B.T. Watson

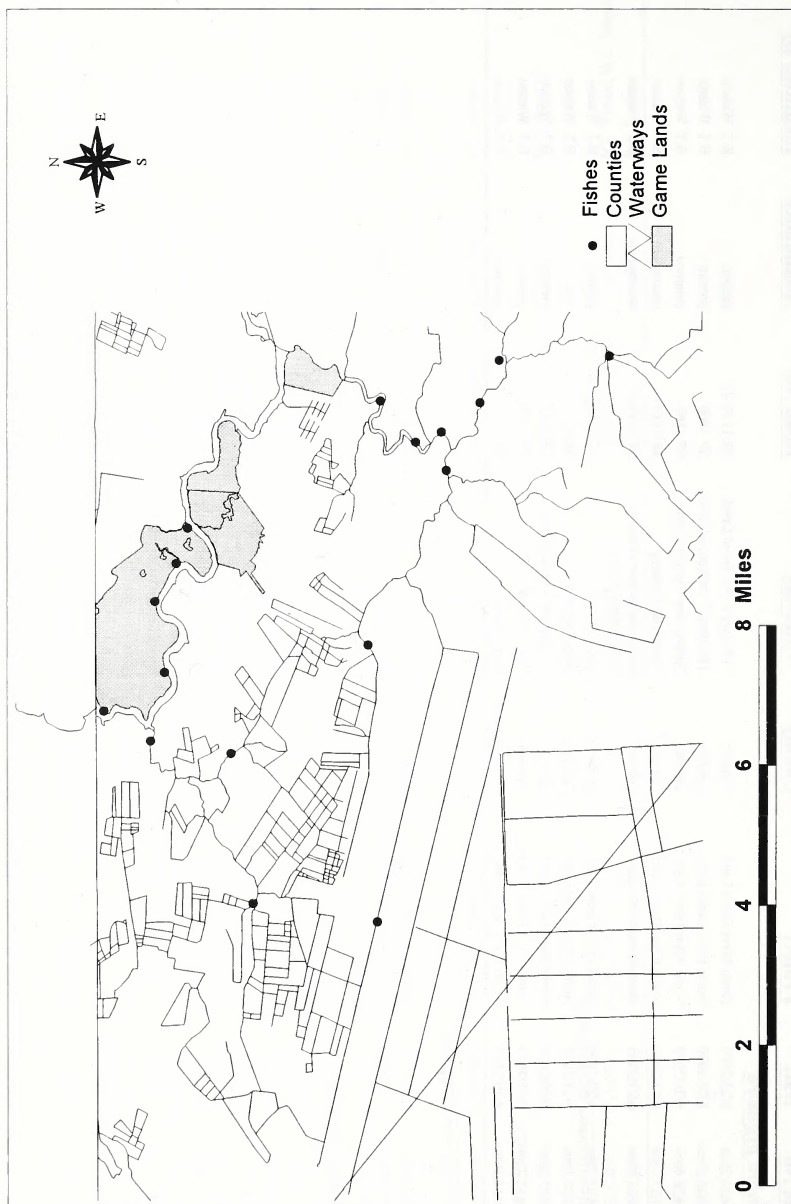


Figure 5b. Map of sites indicating where fishes were collected in the Northwest River Marsh Game Land aquatic inventory, Currituck County, North Carolina, 2000.

Table 5c. Freshwater fish species found in Northwest River Marsh Game Land and associated waterways.

Amblyopsidae	
<i>Chologaster cornuta</i>	swampfish
Anguillidae	
<i>Anguilla rostrata</i>	american eel
Aphredoderidae	
<i>Aphredoderus sayanus</i>	pirate perch
Centrarchidae	
<i>Chaenobryttus gulosus</i>	warmouth
<i>Enneacanthus gloriosus</i>	bluespotted sunfish
<i>Lepomis gibbosus</i>	pumpkinseed
<i>Lepomis macrochirus</i>	bluegill
<i>Micropterus salmoides</i>	largemouth bass
Cyprinidae	
<i>Notemigonus crysoleucas</i>	golden shiner
Cyprinodontidae	
<i>Fundulus diaphanus</i>	banded killifish
Esocidae	
<i>Esox americanus</i>	redfin pickerel
Percidae	
<i>Etheostoma fusiforme</i>	swamp darter
<i>Etheostoma olmstedii</i>	tessellated darter
<i>Etheostoma serraifer</i>	sawcheek darter
Poeciliidae	
<i>Gambusia holbrooki</i>	eastern mosquitofish

Table 5d. Freshwater fish species found in Northwest River Marsh Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<u>Anguilla rostrata</u>							
000822.1btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	SR 1232 (boat access)	present	B.T. Watson
000822.2btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000822.3btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000823.1btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000823.2btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	present	B.T. Watson
000823.3btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.4btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.5btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	rare	B.T. Watson
<u>Aphredoderus sayanus</u>							
000822.3btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	uncommon	B.T. Watson
000823.1btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000823.2btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	common	B.T. Watson
000823.6btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000824.1btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	present	B.T. Watson
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	rare	B.T. Watson
000824.4btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Guiana Mill Run Canal	SR 1387 +	present	B.T. Watson
000824.5btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	present	B.T. Watson
<u>Chaenobryttus gulosus</u>							
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	uncommon	B.T. Watson
<u>Chologaster cornuta</u>							
000824.4btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Guiana Mill Run Canal	SR 1387 +	present	B.T. Watson

Table 5d (cont.). Freshwater fish species found in Northwest River Marsh Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<u><i>Enneacanthus gloriosus</i></u>							
000822.1btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	SR 1232 (boat access)	common	B.T. Watson
000822.2btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000822.3btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	common	B.T. Watson
000823.1btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	common	B.T. Watson
000823.2btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	uncommon	B.T. Watson
000823.3btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.4btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	common	B.T. Watson
000823.5btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	common	B.T. Watson
000823.6btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	common	B.T. Watson
000823.7btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson
000823.8btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000824.1btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	common	B.T. Watson
<u><i>Esox americanus</i></u>							
000823.1btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
<u><i>Etheostoma fusiforme</i></u>							
000822.2btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000823.6btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.7btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson
000823.8btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
<u><i>Etheostoma olmstedi</i></u>							
000822.4btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Canal to Tull Creek	boat access	present	B.T. Watson
<u><i>Etheostoma serifer</i></u>							
000824.5btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	present	B.T. Watson
<u><i>Fundulus diaphanus</i></u>							
000822.2btw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	present	B.T. Watson
000823.4btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game	present	B.T. Watson
000823.5btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game	present	B.T. Watson

Table 5d (cont.). Freshwater fish species found in Northwest River Marsh Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<i>Gambusia holbrooki</i>							
000822.1bw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	SR 1232 (boat access)	uncommon	B.T. Watson
000822.2bw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	common	B.T. Watson
000822.3bw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	uncommon	B.T. Watson
000822.4bw	8/22/2000	Northwest River Marsh Game Land	Currituck	Canal to Tull Creek	boat access	common	B.T. Watson
000823.1bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	boat access	common	B.T. Watson
000823.2bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	present	B.T. Watson
000823.3bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.4bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	common	B.T. Watson
000823.5bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	common	B.T. Watson
000823.6bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.7bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	common	B.T. Watson
000824.1bw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	uncommon	B.T. Watson
000824.2bw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	common	B.T. Watson
000824.3bw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1222 -	present	B.T. Watson
000824.4bw	8/24/2000	Northwest River Marsh Game Land	Currituck	Guiana Mill Run Canal	SR 1387 +	present	B.T. Watson
000824.5bw	8/24/2000	Northwest River Marsh Game Land	Currituck	Trib to Shingle Landing Ck	SR 1227 @ SR 1313 -	present	B.T. Watson
<i>Lepomis gibbosus</i>							
000823.3bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.4bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000824.2bw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	common	B.T. Watson
<i>Lepomis macrochirus</i>							
000822.1bw	8/22/2000	Northwest River Marsh Game Land	Currituck	Tull Creek	SR 1232 (boat access)	present	B.T. Watson, W.C. Starnes
000823.3bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.4bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	common	B.T. Watson
000823.5bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000823.7bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Shingle Landing Creek	boat access	present	B.T. Watson
000823.8bw	8/23/2000	Northwest River Marsh Game Land	Currituck	Northwest River	boat access @ game land	present	B.T. Watson
000824.1bw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roadside ditch to Cowells Ck	NC 34 (near NC 168)	present	B.T. Watson
000824.2bw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	uncommon	B.T. Watson

Table 5d (cont.). Freshwater fish species found in Northwest River Marsh Game Land and associated waterways.

<u>Site No.</u>	<u>Date</u>	<u>Project</u>	<u>County</u>	<u>Waterway</u>	<u>Road No.</u>	<u>Abundance</u>	<u>Identified By</u>
<u><i>Micropterus salmoides</i></u>							
000823.2btw	8/23/2000	Northwest River Marsh Game Land	Currituck	Roland Creek	boat access	present	B.T. Watson
<u><i>Notemigonus crysoleucas</i></u>							
000824.2btw	8/24/2000	Northwest River Marsh Game Land	Currituck	Roland Creek Canal	NC 168 +	uncommon	B.T. Watson

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